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vidual student. Not more than one-third of the classroom time should be devoted to the solution of the problems on the blackboard, and the remainder of the time should be utilized in oral discussions. In conducting an oral recitation the instructor first asks the question before the whole class, and then calls upon one student to give the answer. This method keeps the whole class alert, which is not the case if the instructor calls upon the student and then asks him the question. It is poor practice for the instructor to keep his textbook open during a recitation, except when the students are required to do the same in order to call attention to an illustration or to a table of figures.

The subject matter should be carefully planned and well organized. The instruction process should consist of a series of steps or exercises, taken in order from the simple to the complex. Textbook or printed notes should be used in every course, and the lesson assignment should be worked out in advance and committed to writing. Copies of the lesson schedules should be given to each student or posted, so that oral directions can be reduced to a minimum, thus conserving the student's time.

Definite organization of instructional staff and of teaching material combined with superior instructors will always result in efficient instruction.

A Review of Literature on the Rusts of Oats, with Notes on Their Distribution in the United States.*

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INTRODUCTION.

Oats are not only one of the important cereals of commerce, but are largely grown and used in almost every agricultural region as a feed crop. Thus the acreage and yield per acre are of local as well as national importance. Any factor or factors which operate to reduce the yield per acre in any locality, therefore, deserve to be carefully studied, always with the object of gaining that knowledge which will be useful in improving or maintaining the yield of the crop.

The rusts of oats must be counted as limiting factors in oat production, not in all localities nor in every season, but nevertheless causing immense average annual losses. A considerable amount of work has been done in this and other countries in the attempt to increase our knowledge of these parasites and their host relationships, and thus to make possible the utilization of effective control methods.

In connection with the writer's work on the problem of rust resistance in oats it seemed desirable to assemble the literature not only of that particular problem, but of the various other phases of experimental work on the oat rusts. This summary of the important literature should be of interest to plant pathologists, plant breeders and agronomists who are working on any phase of oat production, and particularly to those experimenters carrying on rust problems.

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* The material for this paper was prepared during the year 1915-1916, while the writer was doing graduate work at Cornell University. Thanks are due the departments of plant pathology and plant breeding for library and other facilities furnished. The Plant Disease Survey and members of the staff of the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture, and of the state experiment stations, contributed the notes on distribution of oat rusts in the various states.

The notes on geographic distribution, relative to soil and climatic factors, damage, etc., should also be helpful to those workers who must be familiar with conditions in other states as well as in their own.

Carleton (6) discusses the distribution of oats in this country by districts, and in many of these districts mentions rust prevention as one of the needs. The varieties adapted to each district are listed and described, a general classification of varieties is given, and the origin and present world distribution of the crop are discussed.

For further information on the oat crop in the United States, including descriptions of varieties, methods of culture and other agronomic problems, reference may be had to the publications of the United States Bureau of Plant Industry and to those of the several state agricultural experiment stations.

The two rusts of oats are distinct in appearance, distribution, life history, and in their effect on the crop; hence the literature dealing with the two species has been for the most part kept separate, and is so arranged in this paper.

THE CROWN RUST OR LEAF RUST OF OATS.

Puccinia lolii Niels. f. sp. *avenæ.*

= *Puccinia coronifera* Kleb.
= *Puccinia rhamni* (Pers.) Wettst.

This rust having its æcidial or winter stage on species of *Rhamnus* (buckthorn) has been one of the well-known forms since the time of De Bary, who worked out its life history at about the same time that he proved the heterœcism of the black stem rust of grains.

As early as 1791 Gmelin described *Æcidium rhamni* on species of *Rhamnus.* In 1801 Persoon listed what was probably the same rust as *Æcidium crassum,* while Schumacher in 1803 described two distinct æcidial forms—*Æcidium frangulæ* and *Æcidium catharticæ.* Lamarck and De Candolle, in 1805, mentioned several forms—*Æcidium, rhamni-alpina, Æcidium crassum* on *Rhamnus frangula,* and *Æcidium irregulare* on *Rhamnus cathartica.* Link, in 1825, described two cæomas which probably should have been referred to this same group.

Corda (10), in 1837, first described the *Puccinia* stage, on a plant which he determined as *Luzula albida,* a rush. This was evidently a wrong host identification, for no crown rust has since been collected on *Luzula.* The name (*Puccinia coronata* Corda) which he applied, however, has been very commonly used to include the various crown rust forms of grains and grasses, and is still so used by many writers.

In 1854 Westendorp used the name *Puccinia coronata* var. *lolii* Bellk., and in 1862 Preuss published the name *Puccinia sertata.* On the basis of culture work, Nielson (40), in 1875, separated the old *Puccinia coronata* of Corda into two forms; to the one having its æcidium on *Rhamnus cathartica* he gave the name *Puccinia lolii,* retaining the old name for the form producing its æcidium on *Rhamnus frangula.*

In 1862 Plowright (37) gave a fairly complete description of this rust of oats, an abstract of which is here given:

> *Puccinia coronata* is one of our most interesting species on account of the form of the teleutospores. The uredo consists of orange spores more spherical in form than those of *P. graminis.* Is common on cultivated oat, occurs in large patches, it being in this respect quite distinct from uredo of *P. graminis* or *P. rubigo vera.* It is not uncommon on *Holcus lanatus, Lolium perenne, Dactylis glomerata, Avena sativa,* and *A. elatior.*
>
> Teleutospores are subcuticular, cylindrical in form, but wider above than below. Provided with very short stalks inferiorly, but the upper division of each spore is crowned with a variable number of well-developed, curved processes, hence the name.
>
> Æcidium of this *Puccinia* is the *Æcidium crassum* of Persoon. Common upon *Rhamnus frangula* and *R. cathartica.* Æcidium spores placed upon oats give rise in 15-20 days to uredo generation.

In 1889 (38) Plowright published a more extended description of this rust in his well-known monograph of British rusts and smuts.

Klebahn (29) in 1892 performed a series of inoculation experiments, and very definitely established the fact that two distinct groups of crown rusts must henceforth be recognized; for the one forming æcidia on *Rhamnus frangula* he retained the name of *P. coronata* Corda, applying the name *P. coronifera* Kleb to the one producing æcidia on *Rhamnus cathartica.* In this latter group belongs the "form species" *avenæ,* the crown rust of oats.

As Magnus (32), in 1912, has pointed out, however, Nielson (1875) had already made this same separation, and had used the name *Puccinia lolii,* which must then, according to priority, be used instead of the name *P. coronifera* as later (1892) used by Klebahn. Grove (22), McAlpine (31) and Sydow (47) use the name *P. lolii* f. sp. *avenæ,* while Eriksson (14, 13), Pole-Evans (16), Fischer (18), Klebahn (30) and others use the name *P. coronifera* Kleb.

The following abstracts are included because of their general interest in the matter of nomenclature, description, distribution, etc.:

McAlpine (31) states that the crown rust of oats has been collected on *Avena sativa* and *Avena fatua* in Australia, and often occurs with the stem rust.

Grove (22) considers the two forms of crown rust rather as biologic forms than as species, and states that host differences and a few minor morphological characters are the only distinguishing features. Plowright is said to have surmised that there were two crown rusts. As hosts, Grove lists: *Rhamnus cathartica,* on which æcidia are produced in May and June; various grasses; and of the cereals, only oats, *Avena fatua, A. pratensis,* and *A. sativa* are attacked, considerable injury sometimes resulting.

Pole-Evans (16) writes as follows regarding the crown rust of oats in South Africa:

> OCCURRENCE. I have evidence to show that the crown rust of oats does considerable damage to the oat crops in the Transvaal. This rust appears later in the season than *P. graminis.* The æcidium has not been definitely shown in this country.
>
> HISTOLOGY. The appressorium formed by this fungus is very similar to that of *Uredo graminis,* but the substomatal vesicle is of very different shape and gives rise at once to two infecting hyphæ. The haustoria are of large size and cylindrical in shape. The pinhead types so common in the case of *P. graminis* are here rarely met with.

In another paper Pole-Evans (17) writes as follows regarding his work on the crown rust:

> In my previous report I expressed the opinion that I thought it quite likely that the æcidium on *Rhamnus prinoides,* first found by MacOwan in this country, might be connected

with the crown rust of oats; in fact, *Rhamnus prinoides* is quoted by Saccardo as being one of the hosts of this rust. In Europe this rust is heterœcious on *Rhamnus catharticus,* while in the United States *Rhamnus lanceolata* bears the æcidium. Consequently, every endeavor was made to obtain specimens of the æcidium on *Rhamnus prinoides.*

With material gained from Cape Colony, I at once set about inoculating a number of oat plants, but on the following day, on examining some spore material which had been sown in watch glasses of distilled water to serve as controls, I was surprised to find that the æcidiospores had not germinated as ordinary æcidiospores, but as teleutospores. On further examining the nature and character of the fungus, I came to the conclusion that it undoubtedly belonged to the genus *Endophyllum,* and has nothing whatever to do with *Puccinia coronata.* I propose to describe and name this fungus as *Endophyllum MacOwanianum,* n. sp. Naturally, none of the inoculated oats developed any pustules.

Saccardo (41) in volume 7, lists the following as æcidial hosts for *Puccinia coronata: Rhamnus cathartica, R. frangula, R. alpinœ, R. saxatilis* and *R. prinoides.*

Avena (oats) and many grass species are listed as hosts of the uredospore and teleutospore stages. It would seem that he did not at this time recognize the two distinct forms. However, in volume II *Puccinia coronifera* Kleb is described as occurring on *Rhamnus cathartica* (æcidial stage) and on *Lolium, Festuca, Holcus* and *Avena* (oats) in the unredospore and teleutospore stages.

Eriksson and Henning (12) give the following account of their studies on the crown rust of oats:

Puccinia coronata Corda.

1. The "resting stage" of the fungus, in winter. There is no possibility of the living over of rust mycelium, for only spring oats are grown. Grasses infected with this rust produced no new uredo pustules during the winter, hence this rust does not live over winter by this method.
2. The first stage of the fungus, the "promycelial" stage. Teleutospores germinate only after overwintering in the open.
3. From teleuto material from *Avena sativa* positive infection results were secured only on *Rhamnus cathartica.*
4. The second (æcidial) stage resembles closely in manner of appearance that of the stem rust on *Berberis.*
5. The third (uredo) stage was observed on oats in 1892 and 1893 in July and August. Uredospores usually germinate easily.
6. Infection trials were made with uredospores on oats with material collected on *Calamagrostis, Alopecurus, Melica,* and from oats; only the latter gave positive results.
7. *Puccinia coronata* is a "collective" species:
    Series I. *P. coronifera* Kleb. Æcidium on *Rhamnus cathartica* f. sp. *avenœ* on *Avena sativa,* and, according to Nielson, on *Lolium.*
    Series II. *P. coronata.* Æcidium on *Rhamnus frangula.*
    Series III. *P. coronata* var. *himaliensis.* Æcidium on *Rhamnus dahurica.*
8. The fourth (*Puccinia* = teleuto) stage. In general the teleutospores are covered by the epidermis, but open sori have sometimes been observed on certain grasses.
9. The economic importance of this rust is not, generally speaking, very great. There is only in one locality of West Sweden a report of the abundant appearance of crown rust of oats (1890).

Eriksson (14) adopts Klebahn's name for the crown rust of oats, and gives the following account of his own observations and studies:

In 1894 the following specialized forms of crown rust were recognized:

Series 1. Æcidium on *Rhamnus cathartica* = *Puccinia coronifera* Kleb. 1. f. sp. *avenœ* on *Avena sativa.* (2, 3, 4,) f. sp. on grasses.

Series II. Æcidium on *Rhamnus frangula* = *Puccinia coronata* Corda (5) f. sp. on *Calamagrostis.*

Series III. Æcidium on *Rhamnus dahurica* = *Puccinia coronata* var. *himaliensis.*

Series IV. Æcidium unknown (wanting?).

Klebahn later established the correctness of the conception of f. sp. *avenæ*. At this time, however, it was not certain that the forms so set off by their uredo infections would remain so through the æcidial stage. Further infection studies of the forms on grasses and oats were needed. These have been performed during 1895 and 1896.

Teleuto material from oats caused infection on *Rhamnus cathartica, R. grandiflora, R. alnifolia,* not on *R. frangula.* Successful infection of *Rhamnus cathartica* from oats (teleuto material) has been repeatedly secured by the writers, as well as by Klebahn.

All the trials so far made go to prove that every form of crown rust forms its æcidia on *one* (not both) of the groups of *Rhamnus* species.

It is, then, proper now to follow Klebahn in giving specific rank (*P. coronifera*) to those forms producing æcidia on *Rhamnus cathartica,* and (*P. coronata*) to those with æcidia on *R. frangula.* The two forms are also set off by observed morphological differences:

1. The teleutospore sori of *P. coronifera* have a tendency to form a circular group about the open uredo pustules, and to remain for a long time, covered by the epidermis; while in the case of *P. coronata* the teleuto sori are more irregularly distributed, and are often open, *i. e.,* not covered by the epidermis.

A further morphological distinction perhaps also exists in the more abundant occurrence of paraphyses in the uredo stage of the *P. coronata* forms.

Certain it is. as in the stem rusts, that sharply fixed groups exist in the uredo stage. Certain results seem to indicate (in the case of the crown rusts) that the æcidial stage may sometimes act as a bridging host.

The following are the forms established:

I. *Puccinia coronifera* Kleb. Æcidium on *Rhamnus cathartica.* F. sp. *avenæ* on *Avena sativa* (2, 3, 4, 5, 6) on various grasses.

II. *Puccinia coronata* (Corda) Kleb. Æcidium on *Rhamnus frangula.* 1, 2, 3, 4, 5, f. sp. on various grasses.

There are certain grass-inhabiting forms whose æcidial stage is not yet known, and whose correct systematic place is therefore doubtful.

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There have been, then, so far carefully studied no less than thirteen specialized forms of crown rusts, six belonging to *P. coronifera,* five to *P. coronata,* and two whose correct place is not yet known, in addition to numerous crown rusts as yet not at all carefully studied. For these it is well (provisionally) to retain the old collective name *P. coronata.* If one compares the specialization of the crown rusts with that of the stem rusts, certain differences are evident. In the stem rusts (excepting the form on timothy) there are only six specialized forms recognized, occurring on eighteen species of grasses. Some of these six forms occur on grasses belonging to different genera—for instance, the rye rust, which is found on seven grasses; and the stem rust of oats, which occurs on eight grasses, including *Avena sativa, A. elatior, A. sterilis.*

How different are conditions in the crown rusts! In the case of *P. coronifera* there are no less than six specialized races, occurring on eight grasses; and five such in the case of *P. coronata.*

The question occurs, What are the causes of these differences in specialization in two groups of rusts where so many analogies exist?

This question must for the present remain unanswered, for we are just beginning to acquire an understanding of the phenomenon of specialization. This specialization reaches gradually the ultimate condition where a rust is strictly limited to *one* host.

Barberry shrubs are much more common in Sweden than are buckthorns, and as a rule are more abundantly infected with the æcidial stage of rust. The influence of the æcidial hosts has no doubt played a part in the specialization. The crown rusts, then, must more often do without the æcidial stage, and this, perhaps, has resulted in their separation into so many biologic forms.

The stem rust of oats is capable of living on a large number of distinct hosts, and this is taken as an indication of its high "vitality." This view is in agreement with other characteristics of this same rust, viz.:

a. Usual good germination of the spore forms.
b. Numerous infections secured.
c. Destructive effect on the oat crop.

• • • • • • • • • • • • • • •

In Sweden the stem rusts occur (destructively) not only on the four cereals, but on nearly 100 other grasses. It is quite otherwise with the crown rusts. These have as hosts only a limited number of grasses, and of the four cereals only oats is attacked. The crown rusts occur only in certain localities and cause (at least in middle Sweden) no injury worth mentioning.

It is without doubt true that these facts are correlated with or dependent on the sharp specialization to which the crown rusts have attained. The spread of crown rusts from one grass species to another is a very much more unusual occurrence than in the case of the stem rusts. It would even appear that the occurrence of crown rusts depends on (1) the presence of the æcidial host, (2) on the adjacent cultivation of grasses of the same species, and indicates, with the less frequent good spore germination, a lower "vitality" for the crown rusts than that which exists in the stem-rust group.

The crown rusts have not often been seen to occur abundantly in Sweden. It is rather the rule that isolated grasses will be infected, while others of the same species, even though only a few feet distant, will remain free of rust. The crown rust seems, therefore, to be best adapted ("at home") in more southern regions. Thus Rostrup reports crown rust of rye grasses as abundant and destructive in Denmark in 1884, 1885 and 1886. Cases are also known where the crown rust of oats has been very destructive, as in certain parts of Sweden (Tanum, 1890, and Holstein, 1891).

Observations in 1895 have also been made on the injurious occurrence of crown rust on oats. At Svalof (late in July) it was as abundant on many oat sorts as the stem rust, both being in the early stages of development.

The pustules of crown rust occurred only on the leaf blades, those of the stem rusts mostly on the sheath.

A still heavier infection of crown rust was observed (second week of August) at Gottingen. This rust infection was present on all oat sorts, more especially on the most vigorous plants, where it was as abundant and destructive as the stem rust often is, in Sweden. Not only the leaf blades were entirely covered with pustules, but also the lower leaf sheaths, where stem rust itself is characteristically only sparingly present.

Eriksson (15), after further work, wrote as follows:

Comparison of my own results with those of Klebahn, Carleton and other foreign workers has shown us another case where the specialization of a parasite is quite different in two different countries.

NOTE.—The weak limitations of the crown-rust fungus in America stand in sharp contrast to the sharply fixed European forms.

I. *Puccinia coronifera* Kleb. f. sp. *avenæ*. Trials in Sweden, Germany and Austro-Hungary have conclusively shown that *Avena (sativa)* is the *only* host for this particular form.

Near Stockholm, and as well in other parts of Sweden, this rust appears in different years with very different degrees of intensity, and in general is much less common than the stem rust. There are years when the crown rust cannot be found at all in the experimental field. It was, however, very abundant here in 1890, less so in 1892 and 1893, as well as in 1895. None at all was observed either in 1896 or 1897, while in 1898 it was again very abundant.

These varying appearances of the rust in different years cannot be due to the fact that in some years the alternate host was absent, for there were always shrubs of *Rhamnus cathartica* within 500 to 1,000 meters of the experimental oat fields, but these bushes were often nearly or entirely free from rust.

Evidently the crown rust finds in middle and northern Sweden the limit of its distribution, *i. e.,* favorable habitat. Its vitality is relatively lessened, and only when conditions are very favorable does it reach abundant development.

Conditions are quite different on the continent of Europe. In Germany the crown rust is of much greater importance than in Sweden, even perhaps causing greater injury to the oat crop than the stem rust.

Muhlethaler (33) has conducted extensive infection trials with a large number of crown rusts occurring in Switzerland, and has cleared up some of the obscure points which still remained after the work of Klebahn and Eriksson. Æcidial material from *Rhamnus frangula, R. cathartica, R. alpina* and *R. pumila* was used, as well as uredospore and teleutospore material from various grasses.

The following forms are recognized:

1. *Puccinia coronifera* Kleb.

Æcidia on *Rhamnus cathartica* ....
Æcidia on *Rhamnus utilis* host ....
Æcidia on *Rhamnus dahurica* .... of the group Cervispina.
Æcidia on *Rhamnus saxatilis* ....
Æcidia on *Rhamnus imeretina* host.
1. f. sp. *ovenæ* (2, 3, 4, 5, 6, 7, 8, 9); other f. sp. on various grasses.

2. *Puccinia himaliensis* (Barcl.) Diet.
3. *P. alpinæ* coronata.
4. *P. coronata* (Corda) Kleb.

Æcidia on *Rhamnus alaternus* ....
Æcidia on *R. californica* .... group Alaternus.
Æcidia on *R. billardi* ....

Æcidia on *R. frangula* .... group Frangula.
Æcidia on *R. purshiana* ....
and on *Rhamnus imeretina* host.

5. *Puccinia coronata* Corda s. lat. f. sp. meticæ. Æcidial stage unknown.

The crown rust of oats in the United States has quite commonly gone under the old name of *Puccinia coronata* Corda. There is great need of some careful and extensive culture work, for the relation of the numerous crown rusts of grasses to the form on oats is not thoroughly understood, nor are all the possible æcidial connections of these rusts definitely known.

The following species of *Rhamnus* occur in the United States, with ranges as indicated:

Rhamnus alnifolia L'Her. 1788.
Range: British Columbia to Maine, southward to California, Wyoming, and New Jersey. Indigenous.

Rhamnus purshiana D. C. 1825.
Range: British Columbia to Idaho and California.

Rhamnus smithii Greene. 1896.
Range: Southern Colorado.

Rhamnus cathartica L.
Range: European. Introduced to America, where it is used in New England, the Middle states and Ontario as a hedge plant. Has escaped from hedges and become naturalized.

Rhamnus lanceolata Pursh.
Range: In moist soil, Pennsylvania to Iowa, Nebraska, Alabama and Texas. Indigenous.

Rhamnus caroliniana Walt.
Range: In wet soil, Virginia and Kentucky to Kansas, Florida and Texas.

Rhamnus frangula L.
Range: In bogs, Long Island and New Jersey. Reported from Ontario. Naturalized from Europe.

Of these the writer has found records of the occurrence of the æcidia of crown rust of oats only on *R. cathartica, R. lanceolata, R. alnifolia* and *R. caroliniana.* Prof. H. S. Jackson, formerly of the Oregon Agricultural College, states (see "Notes on Oats and Oat Rusts from Oregon," in this paper) that "*R. purshiana* is commonly infected with an æcidium," but from the results of Muhlethaler (above cited) it would seem doubtful whether this species is a host for our crown rust of oats. *Rhamnus frangula* is not as commonly used for a hedge plant as *R. cathartica.* Little is known of the relation of any of our crown rusts to this possible winter host.

Pammel (35) gives *Rhamnus frangula* as a host for the crown rust of oats, and says: "It is found in several places in Iowa, but it is certainly not common."

Pammel (36) further states that the two rusts of oats have been so serious during the last few years that the crops have been very light. The spraying experiments were repeated in 1893, but there were no appreciable differences observed between the check and the sprayed plats.

Although the identity of our American forms is not as firmly established as would be desirable, it is thought the evidence is sufficient to warrant the use of the nomenclature adopted here; that is, to drop the old collective name, *P. coronata,* and to use either *P. coronifera* Kleb., or, if the rules of priority are strictly followed, the name here used (*Puccinia lolii* Niels.) is the proper one.

Arthur does not use either of these names, but goes back to the specific name used before Corda's description of the Puccinia stage, *i.e.,* to the binomial *Æcidium rhamni,* and thus derives the name he now uses, *Puccinia rhamni* (Pers.) Wettst.

The following abstracts from accounts published in America of the occurrence, distribution, relationships and other characters of the crown rust will give a fairly good idea of the present state of knowledge of crown rust in this country:

Thaxter (48) reported in 1889 that both the crown and the stem rust had been injurious to oats in Connecticut, the first-named rust being the most destructive.

Kellerman (28), in connection with his report on spraying to prevent rust, makes the following statement regarding the crown rust of oats:

> On July 2 the oat plats showed much red rust (*P. coronata*). Adjacent fields of oats were likewise affected. Later examination revealed no difference in the amount of rust in the treated and untreated plants. They were all equally affected, with the possible exception of the Bordeaux treatment, where there seemed to be, perhaps, a little less rust on the stems than in the other plats.

Hitchcock and Carleton (25), 1893, report that the æcidial stage of the crown rust of oats is formed on *Rhamnus lanceolata* and on some other species of the order Rhamnaceæ.

In a second report (26), 1894, they state that while in 1892 the crown rust was the predominant one on oats, with very little of the stem rust, in 1893 *none* of the former species was found on any host in the vicinity of Manhattan, Kan., while the latter (stem rust) was very abundant.

Underwood and Earle (50) reported "*Puccinia rubigo-vera*" on oats (*Avena sativa*) as having been collected (1890) in Lee county, Alabama, by Professor Atkinson. The rust referred to is probably the crown rust.

Henderson (23), 1898, states that so far the crown rust is very rare in Idaho.

Arthur and Holway (1) in 1898 published a detailed description of the crown rust, which is given below:

Puccinia rhamni (Pers.) Wettst. 1885 in Verhl. Zoöl. Bot. Wien., 545.
Hosts:
II. *Avena sativa, fatua.*
I. *Rhamnus lanceolata.*
R. alnifolia.
Æcidium crassum Pers.

Syn. *Æcidium rhamni* Pers., 1791.
Puccinia coronata Corda, 1837.
Probably also *Æcidium pulcherrium* Rav. on *Berchemia,* as described by Berkeley, N. A. Fungi, Grev. 3, 61.

I. Æcidia on somewhat thickened definite spots on lower side of leaf, occasionally causing considerable distortions, especially when on young fruit and shoots; at first orange, becoming nearly colorless with age; margin erect, somewhat erosed; æcidiospores orange yellow, becoming pale yellow with age; isodiametric or somewhat elongated, polygonal; 16-24 microns in diam.; wall thin, minutely granulose.

II. Uredo sori of medium size, oblong to linear, on both leaf surfaces, occasionally on sheaths and stems; scattered, rarely confluent, but sometimes clustered, soon naked; orange-colored; ruptured epidermis prominent. Uredospores globose, some admixture of obovate globose; 22-30 microns in diam.; wall colorless, thin, obscurely echinulate; pores four or more, scattered. Contents orange when fresh, becoming yellow on drying.

III. Teleutospore sori on both leaf surfaces, but more abundant on under side of blade; less common on sheaths and stems, scattered; irregularly oblong, partly fructiform, covered with the persistent epidermis, grayish black. Teleutospores subclavate to linear oblong, 35-60 x 15-18 microns, slightly or not constricted; wall thin, smooth; apex not much thickened, but produced into finger-form projections, either erect or more or less inclined, corona like; base somewhat narrowed; pedicel very short or obolescent.

This is a species the limits of which are not easily defined. Arthur secured typical uredo on oat leaves by sowings made (1898) from æcidia on *Rhamnus lanceolata.*

We have no opinion at present to offer as to Klebahn's separation of the two forms. It is believed the material at hand is properly referred to the one species, *P. rhamni.*

Carleton (5) in 1899 published the following observations on crown rust: *Puccinia coronata* Corda.

PHYSIOLOGICAL RELATIONS. The most distinct of all the cereal rusts, superficially and microscopically very different from the black stem rust. The uredospores are, however, similar (in shape) to those of the leaf rusts of wheat and rye.

Although the rust does not seem to occur in nature on very many wild grasses, several of these were infected with it when inoculated in the greenhouse.

Successful on—
  Oats:
    Siberian.
    Black Tartarian (doubtful).
    Avena fatua.
    Nackter Kleiner. Fahmen.
    Etampes.
    Fenton's Rust Proof.
    Avena pratensis.
    Ligowa.
    Dun.
    Avena sterilis (only 1 or 2 spots).
Usual incubation period is 7 to 10 days.

Additional hosts: *Avena sativa patula, A. sativa orientalis, A. sativa nuda.*

Other species of *Avena* that will probably be found to act as hosts are: *Avena fatua, A. pratensis, A. hookeri, A. sterilis.*

Grasses:
  Hoddeum murinum (1 or 2 spots).
  Phleum pratense.
  Dactylis glomerata.
  Aira cæspitosa (1 or 2 spots).
  Holcus mollis (doubtful).
  Eatonia sp.
  Kœleria cristata.
  Anthoxanthum odoratum.
  Festuca sp.
  Alopecuris alpestris.

Grasses—*Concluded*:
Phalaris arundinacea.
Trisetum subspicatum (1 or 2 spots).
Brizopyrum siculum (doubtful).
Phleum asperum.
Poa annua (1 or 2 spots).

It is suggested (and this was evident from trials made on more mature plants) that results differed from field conditions in that (1) young plants were used and (2) greenhouse conditions were more favorable for rust propagation.

Certain plants which had been successfully infected when quite young were inoculated at a more advanced age. The result was that infections did not occur at all or were very slight and evidently took place with difficulty.

Infections on grasses (using uredo from oats) are recorded, but none on oats using uredo from wild grasses.

Æcidial material from *Rhamnus lanceolata* resulted in the infection of—
Oats:
Phalaris caroliniana.
Arrhenatherum elatius.

OCCURRENCE AND DISTRIBUTION. The crown rust seems to be quite analogous to the leaf rust of wheat. It is the more common of the two rusts of oats in the United States. Compared with the stem rust, it seems to be especially prevalent in the Atlantic and southern coast states, where the urego stage is very likely able to live over the winter.

Apparently the crown rust is not as constant in its occurrence from year to year as the leaf rust of wheat, though the writer is not certain of any instance where it was entirely absent during the entire summer.

Although one of the most prominent rusts in the United States, it seems strangely enough to be rather insignificant in most other countries.

The writer knows of no instance where it could be proved that this rust caused any really serious damage to oats, under ordinary conditions, when the black stem rust was not also present, but nevertheless it is quite possible that it may occasionally cause considerable injury. In any event, the crown rust seems to be of more economic importance in the United States than in most other countries.

Clinton (9) in 1903 reported the crown rust as common on the leaves of oats.

Carleton (7) in 1904 reported further work on the crown rust of oats as follows, and in this publication used the name *Puccinia rhamni* (Pers.) Wettst:

In the same season in which Doctor Arthur obtained infections on oats from the æcidium of *Rhamnus lanceolata,* the following experiments were conducted:

August 30, 1897: Inoculations from crown rust on *Phalaris coroliniana* to oats resulted September 7 in a good infection; to orchard grass, poor; to wheat, none.

September 1: Inoculations made on wheat and rye, but with no result.

December 11: Inoculations were made (from uredo material of crown rust found on *Arrhenatherum elatius*), on oats and rye; good infection resulted on the oats in twelve days, none on the rye.

February 16: Further inoculations on oats with the rust from *Phalaris* gave again a good infection in nine days.

Rhamnus lanceolata at Weeping Water, Neb., is often badly rusted with an æcidium.

June 1 and 2: Inoculations were made with these acidiospores on oats and *Phalaris caroliniana,* resulting in a successful infection of *Phalaris* on June 14 and of oats on June 18.

These experiments prove the connection of the æcidial form cf *Rhamnus* with the crown rust of oats, and show also that *Phalaris caroliniana, Arrhenatherum elatius,* and probably orchard grass, *Dactylis glomerata,* are also hosts for the crown rust.

Christman (8) studied the wintering of oat-crown rust at Madison, Wis., during the winter of 1902-1903, and his conclusions were as follows:

It is plain that in the latitude of Madison, and with a period of three months during which the temperature scarcely rises above the freezing point, viable uredos may be obtained at practically any time during the winter.

An oat plant was covered (snow and under glass) and the development of "flecks" watched during the winter, and pustules (opening the epidermis) formed. (It seems probable

> that uredos and mycelium of the crown rust are at least as resistant as the oat plants on which they grow.) Uredos from oats were germinated as late as January 26, and it seems probable that the mycelium would have withstood the remainder of the winter if the host could have been kept alive. In cooler weather of spring the incubation period is three to four weeks. Spores may be carried in fairly large numbers by the wind.
>
> At Madison the uredos may remain dormant for long periods without losing their vitality, but these "old" spores may very likely play little part in producing spring infection, since on the first warm days the mycelium produces new pustules and a fresh crop of spores.
>
> As the severity of the weather must affect the amount of healthy host tissue that survives the winter, it must limit the amount of mycelium and so the number of uredos at hand in the spring, and is probably one of the chief factors in determining the violence of early outbreaks of the rust.

Bolley and Pritchard (3) in 1906 state that oats are generally attacked by the early lemon-yellow leaf rust (crown rust).

Olive (34), in 1908, gives the following note as to the occurrence of crown rust of oats in South Dakota:

> This rust has its spring stage on the buckthorn, which is a well-known plant and is very commonly used for ornamental hedges throughout South Dakota, being even much more employed for this purpose than barberry. During this past spring hedges of this plant have been everywhere viciously attacked by the yellow cluster-cup stage, stunting the leaves and deforming and twisting the young stems. We should consequently expect the rust on oats to be especially virulent during the wet season, especially if further favorable conditions for the rust are furnished by a series of warm, muggy days.
>
> Control measures suggested are:
>
> 1. Drainage.
> 2. Destroy æcidial hosts.
> 3. Destroy wild grasses harboring the rust.
> 4. Selection and breeding of immune forms.

Selby (43) reports crown rust common on oats in Ohio, usually prevalent during the rainy harvest weather and more or less in evidence at all times.

Warburton (51) writes as follows concerning the rusts of oats:

> The rusts are easily recognized by the appearance of irregular roughened areas on the leaves and stems, which at maturity discharge large numbers of red or black spores. The most common rust of oats is the crown rust, usually known as the red or leaf rust, though the stem rust also commonly occurs on this grain. The crown rust does not injure the crop as seriously as the stem rust, which, when it occurs, makes its appearance a few days later than the crown rust and is likely to do serious damage. These rusts take the food from the stems and leaves of the oat plant, that would naturally go to the development of the grain, which is, as a result, light and shriveled. No accurate estimate of the damage done by the rusts can be made, but it is probably even larger than that done by the smuts.
>
> There are no known means of combating the rusts when they occur. The damage may be somewhat reduced, however, by early planting or by the planting of varieties which mature before the black rust develops, and by planting on well-drained land, as moisture is essential to the development of rust. The red rustproof oat is quite resistant to rust in the South, where the disease is usually prevalent, but is much less resistant in other sections. Drilled oats are less liable to injury from rust than those sown broadcast, as light and air can penetrate between the drill rows. Rank growth resulting from rich soil, excess of nitrogenous fertilizer, or abundant moisture, also favors rust.

Reed and Holmes (41) in 1911-1912 made a study of the winter resistance of the uredospores of the crown rust of oats at Blacksburg, Va., and reported on their work as follows:

> This work was begun in the fall of 1909 to determine whether the crown rust of oats can be carried over the winter by the uredospore, at Blacksburg. Located in an elevated portion of the intermountain valley, at an elevation of 2,200 feet above sea level, the winters here are much more rigorous than in many other parts of the state. Carleton has expressed the opinion that the uredospore of this rust hibernates successfully in the warmer parts of the United States.

The crown rust causes little damage as a rule, although it is more common than its more destructive relative, *P. graminis avenæ,* the stem rust.

The observations here reported were made upon two plats of oats; one was an area of volunteer (summer) oats, the other was a plat of winter oats. The plants on the former plat were dead by December 1, but the plants on the other plat remained green throughout the entire winter. The plat of volunteer oats was designated "A," the winter oats as plat "B." In November the tufts of oats in each plat that were badly infected with rust were marked with a stake so that material could be easily secured from the same locality from month to month.

The viability of the spores was tested in a modified Van Tieghem cell, using the "hanging drop" method, at room temperature (between 18° and 24° C.).

The results of the tests are shown in tables XIV and XV.

TABLE XIV. Germination tests of uredospores of *P. coronata* from plat "A."

Date. *1909.*	*No. of tests made.*	*Per cent of germination.*	*Remarks.*
Nov. 1	5	100	
Nov. 15	5	85	
Dec. 1	5	40	All plants of the plat were dead at this time.
Dec. 15	5	25	
1910.			
Jan. 5	5	20	
Jan. 15	5	25	
Feb. 1	3	15	
Feb. 15	5	20	
Mar. 1	3	5	The germination in this case was rather doubtful.
Mar. 15	5	0	
April 1	5	0	

TABLE XV. Germination tests of uredospores of *P. coronata* from plat "B."

Date. *1909.*	*No. of tests made.*	*Per cent of germination.*	*Remarks.*
Nov. 1	5	100	
Nov. 5	5	90	
Dec. 1	5	60	
Dec. 15	5	35	All growth seemed to cease.
1910.			
Jan. 5	3	10	
Jan. 15	3	0	
Feb. 1	5	10	
Feb. 15	3	10	
Mar. 1	5	20	Growth began to be resumed.
Mar. 15	5	25	
April 1	1	50	Oats in a growing condition.

The figures presented in these tables, brief though they are, show that the uredospore, under natural climatic conditions, may and does retain its vitality on winter oats and to a limited extent upon volunteer summer oats. On winter oats it seems that the crown rust has an enduring mycelium and produces uredospores during much of the winter. In table XV the results obtained during January and February are interpreted to mean that the fungus mycelium had ceased to produce spores, and that those still attached to the surface of the plant were losing or had lost their vitality. When conditions ensued which were more suitable for growth, the mycelium began to produce spores, and on April 1 it appeared that 50 per cent of them were capable of germination. Johnson has reported that the minimum temperature for the germination of the uredospores of this fungus is 7° to 8° C. Somewhat similar conditions seemed to exist in the case of the volunteer oats which did not survive. There the vitality of the uredospores seemed to fall off in much the same way, but since the host plant was dead the mycelium did not begin to form new crops of spores with the advent of warmer weather.

The relation of spore vitality to temperature is, of course, more or less obvious. Some records were made from the meterological observations taken at Blacksburg. It was noted that in a general way the percentage of viable spores on the winter oats (plat "B") corresponded to the temperature curves. Although the oats ceased to grow after December 15, the fungus appeared to be in condition to furnish viable spores practically all winter. In the case of spring oats (plat "A") the percentage of viable spores dropped, during the first six weeks, nearly parallel with that of plat "B," but after February 15 it fell off still more rapidly, while the other curve rose. It would appear then that where the host plant lives over winter that temperature is the principal factor limiting spore germination of this rust. Where the host plant dies, time appears to be the more influential factor limiting spore germination.

Davis (11) listed (1914) the crown rust on oats, *Avena sativa,* and on *Calamagrostis canadensis* and *Dactylis glomerata,* both uredospore and teleutospore stages, and the æcidial stage on *Rhamnus alnifolia* and *Rhamnus cathartica.*

Burnham and Latham (4) in 1914 reported the occurrence of the æcidial stage of crown rust on leaves of *Rhamnus cathartica,* and the uredospore stage on leaves of *Avena sativa.*

Fromme (21) in 1914 made a study of the influence of light on the germ tubes of uredospores of the crown rust, and found a negatively heliotropic reaction, *i. e.,* the germ tubes grew away from the light. This fact may possibly have a bearing on certain phases of infection; that is, on the stimuli which are responsible for the stomatal entrance of germ tubes.

Freeman and Johnson (20), in 1911, state:

> The crown rust almost invariably accompanies the stem rust and is probably the most destructive of the leaf-rust group. The crown rust often occurs on the leaf blades, commingled with the stem rust, making it difficult to determine how much of the damage is due to each. The crown rust is, however, seldom found on the spikelets or spikelet stems.
>
> Oat rusts are found extensively only east of the dry belt of the Great Plains region, with the possible exception of eastern Oregon and Washington.
>
> In the gulf coast states, except northern Texas, and in Georgia and South Carolina they are paramount in importance and almost prohibitive of spring oat growing, though winter oats are quite extensively grown. Proceeding northward, these rusts continue to be of great importance.
>
> Even as far north as Wisconsin, regions are known where oat growing has been discontinued on account of rust, and epidemics have been known to extend to the Canadian line and even beyond.
>
> There is great variation in time of ripening of different varieties, two to four weeks in some latitudes, and if, as is usually the case, the epidemic appears suddenly, a difference of one week may decide whether a variety is destroyed or reaches normal maturity.
>
> Both the crown rust and stem rust of oats were cultured for fifty-two successive generations in the uredo stage without any apparent diminution of vitality. This number of artificial inoculations will easily represent a period of seven or eight years of successive infection in the field, as eight to twelve days or more are there necessary for each infection to appear, and it is not likely that more than five or six successive infections follow each other during one crop season.
>
> Rust uredospores germinate either not at all or not nearly so well at 90° to 100° F. as at 55° or 75° F. The crown rust of oats, however, is noticeably resistant to heat, while the stem rust of oats is quickly injured.

These two facts, namely, that the uredospores of the crown rust are noticeably resistant to heat, while the stem rust is easily injured by it, are believed to have an important bearing on the distribution of the two forms over the country, and go to strengthen the view that the crown rust is much more widespread and injurious in the more southern localities, while the stem rust usually reaches its highest development in the form of devastating epidemics in the Northern states. This view is in strictest agreement with that of Eriksson, stated in his paper already quoted.

Carleton did not demonstrate the wintering of the uredo of the crown rust or of the stem rust of oats, although it is his opinion that the crown rust passes the winter in the uredo stage in the warm latitudes of the United States.

The great problem of rusts in many places of the South, however, is not how to live over the winter, but how to pass through the extremely hot months of July, August and September, especially where volunteer grain or wild grasses are scarce at this season.

NOTE.—Careful studies of the wintering of the crown rust and stem rust of oats have not been made, and a discussion of them is omitted.

Undoubtedly the first appearance of these rusts in the spring will also be found to result from wintering of the uredos and windborne spores (as well as from æcidial infection).

Hewitt and Stone (27), 1915, make the following statements regarding crown rust of oats in Ontario:

> This rust is mainly confined to the leaves, though it may occur to some extent on the leaf bases and stems. The leaves and leaf bases may become thickly covered early in the season with small oval or elongated, light red or orange-colored spots (uredo sori). Later these same spots in turn are replaced by grayish-black spots of teleuto spores, remaining covered by the epidermis, and frequently arranged in circles around the old spots of the red rust.
>
> This leaf rust of oats forms an exception to the general rule that leaf rusts do not do a great deal of damage, for the attacks of this rust sometimes damage the oat crop very considerably.
>
> Life history similar to that of stem rust, except that æcidial stage occurs on buckthorn, not on barberry shrubs. *Rhamnus cathartica* is a native of Europe and is much used for hedges, and is also now escaped from cultivation. It is believed that it would pay farmers to destroy all of these shrubs growing in or near oat fields, and thus do away with at least one of the means by which oat rust is so abundantly multiplied.

Fraser (20) in 1915 published the following note on the occurrence of crown rust of oats at Macdonald College, Quebec:

> Æcidial stage on species of buckthorn (*Rhamnus*). Uredospores and teleutospores are produced abundantly on the leaves of oats. The teleutospore masses do not break through the epidermis, as in the stem rust. The teleutospores are easily recognized by their projection at the apex, hence the rust is sometimes called crown rust of oats.
>
> Both stages of this rust are rather common in late-sown oats on the college farm, but the early oats are not attacked. The æcidial stage is usually present in the buckthorn shrubs on the college campus.

From the above statements it is evident that the crown rust is of worldwide distribution, that it is highly specialized, and that its life history is not completely worked out in the United States.

The life history of the crown rust may be briefly characterized as follows:

SPORE FORMS.

0. Spermogonia first appear in April, May or June, on the upper surface of leaves of buckthorn.

I. In a few days æcidia break through the lower surface and the yellow æcidiospores are soon shed.

II. If these æcidiospores fall on leaves or other parts of an oat plant they cause there an infection which in eight to fourteen days gives rise to the uredospore pustules. These occur mainly on the leaf blades, although in severe cases of infection the sheaths may become infected, and even the peduncles and spikelets. The uredospore generation may be, and often is, repeated during the season, and thus spreads the fungus to other fields. The uredospore sori are of a bright salmon-orange color, medium in size, rounded oblong (not linear), and sometimes become confluent. The uredospores are nearly round, warty, have several germ spores, and are bright in color when fresh.

III. The teleutospores are formed in the same or similar pustules as the uredospores, but these remain, at least for some time, covered by the epidermis, thus appearing grayish, not so black as in those of the stem rust, which soon rupture the epidermis.

The teleutospores are brownish-black, thick-walled, and the upper cell is provided with a crownlike apex of finger-form processes; hence its name, crown rust. The teleutospores will only germinate after a winter's rest, and then the sporidia so formed will cause infection only on leaves of buckthorn.

BLACK STEM RUST.

Puccinia graminis Pers. f. sp. *avenæ* Erikss. and Henn.

The familiar stem rusts of grain have been known, feared by farmers and investigated by botanists perhaps as long and as much as have any other plant parasites. Eriksson and Henning (13) give the following notes as to the history of the stem rust, and list the various names by which it has been known, in part as follows:

> The first mention of the acidial form in literature was by Jacquin, in 1786, as *Lycoperdon poculiformis.* Gmelin, 1791, described it as *Æcidium berberidis.* Lasch described the form on fruits of the barberry as a distinct variety, *fructicolum* (*fructigenum*).
>
> 1875. The form on *Mahonia* was described in England by Berkeley and Broome, and in Germany by Magnus.
>
> 1883. Plowright's work on the teleuto form.
>
> 1884. DeBary's work on the teleuto form. (He had earlier proven the heterœcism of the fungus.)
>
> The uredo and teleuto stages were first described by Felice Fontana, 1767. They were only known by the scientific name ten years later.
>
> 1801. Persoon used the name *Puccinia graminis* as *Uredo linearis frumenti,* and Lambert, *Uredo frumenti.* The fungus has since been known under a number of names:

1803.	Schumacher II	*Uredo ferruginea.*
	III	*Uredo culmorum.*
1810.	Strauss	*Uredo linearis.*
1817.	De Martius	*Uredo frumenti* (*linearis*).
		Puccinia cerealis.
1824.	Linck	*Cæoma lineare.*
		Puccinia graminis.
1833.	Wallroth	*Erysibe linearis.*
		Puccinia graminis.
		Puccinia culmorum.
		Puccinia vaginarum.

> 1888. von Wettstein. Verarbeitem zu einer Pilz flora der Steiermark. In Verh. d. K. K. Zoöl. Bot. Gesellsch. in Wien. Bd. 38. 1888. Wien. On grounds of priority calls it *Puccinia poculiformis.**

Plowright (38) gave an accurate description of the stem rust, listing *Berberis vulgaris* and *Mahonia ilicifolia* as æcidial hosts, and *Avena sativa* and other cereals and grasses as hosts for the uredospore and teleutospore stages.

Grove (22) gives a historical account of the fungus (with synonomy) and detailed descriptions of the various spore forms. He further states:

> This rust is much less common in England now than some of the other cereal rusts. This is, perhaps, due to the extirpation of wild barberries; the æcidium is really uncommon even on cultivated species of Berberis and Mahonia.

---

* Arthur still uses this name. The authority for such usage goes clear back to the first description (1786) where *poculiformis* was used as the species name. This is not, however, in accord with the International Code, which provides that nomenclature in the rusts, using the teleutospore form, shall date from Persoon, 1801.

McAlpine (31) describes only the spore forms occurring on grasses and cereals, and states that he has never seen the æcidial stage in Australia, nor has he ever been able to produce it from artificial inoculation, though the stem-rust fungus of cereals there seems to resemble in every other way the form in other countries.

Sydow (47) gives the complete list of synonyms used, describes the spore forms, and makes rather brief reference to the history of the development of opinion and knowledge regarding the connection of grain rust and the barberry.

Eriksson and Henning (13) give a very extensive and complete account of the life history of the stem rust, description of the spore forms, and of their work on biologic forms. They list as æcidial hosts, according to their own observations, *Berberis asiatica, B. buxifolia, B. canadensis, B. vulgaris* and *Mahonia aquifolium.* In addition, the following are listed on the authority of other workers: *Berberis attaica, B. amurensis, B. aristata, B. carolinæ, B. ilicifolia, B. nepalensis, B. neubertii,* and *Mahonia glauca.*

Fischer (18) describes the fungus in some detail, lists the several æcidial hosts, but states definitely that the fungus will *not* infect *Berberis thunbergii,* or *Berberis chinensis.*

Klebahn (30) gives a very excellent historical account of the gradual accumulation of evidence against the barberry. Abstracts from his account follow:

> As early as 1660 there were laws requiring the extermination of barberries. (Rouen Parliament.)
>
> In England the harmful influence of barberries was noted early in the eighteenth century. (1758.)
>
> In 1776 Withering wrote: "This shrub should never be permitted to grow in 'corn' lands, for the ears of wheat that grow near it never fill, and its influence in this respect has been known to extend 300 to 400 yards across a field."
>
> In 1715 Massachusetts passed a law for the extermination of barberries.
>
> Other North American observers also noted the injurious effect of barberries.
>
> In Germany, 1803, Treviranus spoke of barberries as causing "Misswachs" in grain.
>
> In 1815 the Bremen senate ordered the extermination of all barberries within 500 feet of grain land.
>
> Many observers (Sowerby, 1790, in England) were aware of the effect.
>
> Experimental proofs were only attempted at the end of the eighteenth century. (See Marshall, 1782, in "The Rural Economy of Norfolk." See copy in Plowright, p. 48, 2d ed. (1795), 359.) Cause of the injury was first attritbuted to the pollen of the barberry; later observers considered there *was* really a connection between "*Æcidium berberidis*" and "*Uredo linearis*" of the grain.
>
> Willdenow concluded the surface of the plant determines whether a fungus will be an æcidium or uredo.
>
> In 1804 there was a severe epidemic and an inquiry as to effect of barberry.
>
> See Banks, 1806, who gave good account and illustrations of the "blight" of "corn" and supposed (but without experimental proof) that the barberry æcidium "seeds" passed into the wheat.
>
> In 1813 Thos. A. Knight believed the barberry communicated the disease to wheat.
>
> In 1805 Sprengel pointed to the possible relation of *Æcidium berberidis* and *Puccinia graminis.*
>
> Injurious working of the barberry was also early recognized in Sweden, 1806; Denmark, 1797.
>
> In 1807 Scholer (a little later) planted out 8,000 barberries, and in 1810-1811 he ran experiments which led him to believe in the intimate connection of the barberry and rust of rye. In 1812 he definitely concluded that, with aid of the wind, rust of barberry goes to rye and again to the *Berberis.*
>
> Hornemann of Copenhagen disagreed with Scholer.

In 1864 studies of other workers, De Bary, Tulasne *et al.*, cleared up the matter by actual scientific experiment and observation of spore formation and infection, teleutospores from *Agropyron repens* to *Berberis*, and æcidiospores from *Berberis* to *Secale cereale.*

In spite of this work, Orsted cast doubt, 1880, on the connection (identity) of the two fungi.

W. G. Smith observed æcidia in seeds of barberry, teleutospores in oat seeds, and held that the disease could arise directly from this source of infection. Even Plowright somewhat distrusted the doctrine of heterœcism.

In 1884 Plowright experimented with material from the United States (*Agropyron repens*) and produced æcidial infection.

In 1889 Bolley passed wheat rust to barberry.

In 1899 Carleton passed barberry rust to barley and other hosts.

Lists of "united" hosts have been increased by various workers: Plowright, DeBary, Eriksson, Barclay *et al.*

Æcidial hosts now recognized are: *Berberis vulgaris, B. lycium, B. canadensis, B. nepalensis, B. aristata, B. amurensis, B. atro-purpurea, B. ilicifolia, Mahonia glauca, M. aristata, M. altaica = silurica,* and *M. aquifolium.*

Even though the connection of rusts of cereals with the barberry is now proven, it is still a question of importance, for the number of barberries occurring seems to be not very large; by many farmers the shrub is entirely unknown.

Saccardo (42) lists the æcidial hosts of stem rust and the complete list of grasses on which the form has been collected. A list of synonomy and the usual descriptions (in Latin) of the spore forms are also included.

Henning (24) has published a brief note on the occurrence of the stem rust of oats at Ultuna, Sweden.

In the United States the stem rust of oats has long been reported from almost all oat-growing sections, and probably is the rust most often referred to in accounts mentioning severe damage from "oat rust," but not naming the species of rust present.

The manuals of botany and floras consulted give the following species of *Berberis* as occurring (wild) in the United States:

Berberis nervosa Pursh. 1814.
  Range: British Columbia, Washington, Oregon, Idaho. Indigenous.
Berberis aquifolium Pursh. 1814. (Also called *Mahonia.*)
  Range: British Columbia, Washington, Oregon. Indigenous.
Berberis repens Lindl. 1828.
  Range: British Columbia to California, Wyoming and New Mexico. Indigenous.
Berberis fremontii Torr. 1859.
  Range: Infrequent, canyons of Southwestern Colorado to Mexico. Indigenous.
Berberis fendleri Gray. 1848.
  Range: Southern Colorado and southward. Indigenous.
Berberis vulgaris L.
  Range: European. Naturalized in Eastern and Middle states of United States.
Berberis canadensis. Mill.
  Range: Woods and mountains of Virginia to Georgia and in Missouri.

Bailey (2) states that in addition to these, several cultivated varieties and horticultural species are present, at least in many parts of the country. It is impossible to say positively whether all of these harbor the stem rust, though it is a well-known fact that *Berberis vulgaris* and its purple-leaved variety, *atropurpurea*, are commonly infected with this rust. As already mentioned, it is pretty certain that *Berberis thunbergii* never is infected.*

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* At Cornell University, during the spring of 1916, heavy infections were produced on young plants of *Berberis vulgaris atropurpurea* growing in the greenhouse, simply by tying around them bundles of straw bearing germinating teleutospores of the stem rust of oats. The spermogonia on the upper leaf surface were distinctly visible in six days; the æcidia on the lower leaf surface appeared a few days later.

Plants of *Berberis thunbergii* treated in exactly the same manner showed no signs of infection. This experiment would seem to establish the fact of the immunity of the Japanese Barberry.

Thaxter (49) reported in 1889 that stem rust had been injurious to oats in Connecticut.

Hitchcock and Carleton (26) in 1894 reported on their experiments on the wintering of grain rusts in Kansas, and state that:

> It seems probable that the stem rust does not pass the winter in this vicinity in the uredo stage nor in the mycelial condition. Whether or not it survives the winter further south is a question yet to be answered.

Concerning the occurrence of the stem rust in 1893 they wrote as follows:

> *Puccinia graminis* appeared during the season (June) on the experimental oats of the farm department, and finally became so abundant that by harvest time the crop was very materially injured. Indeed, this season the oat crop in large portions of the state was much injured by this rust. In Wabaunsee county some fields were almost wholly destroyed and the straw so badly lodged that it could scarcely be harvested.

In 1898 Arthur and Holway (1) published a description of the stem rust, and with it their explanation for dropping the long-used and very familiar name *Puccinia graminis*. The defense of their position, as stated by them, is here given:

> Experience does not seem to bear out the inference that the teleuto stage alone possesses such marked superiority for specific identification. It is unfortunately true that much doubt often attaches to the application of early names, but an arbitrary contraction of the domain to be covered by the law of priority does not seem to the writers to be the right way to meet the difficulty.
>
> It is not sufficient to give as a host for a rust "various grasses," but is even necessary to name specifically the plant and the part affected. Value in classification of both the uredo and æcidial stage is now recognized, and the old exalted view of the all-importance of the teleuto stage can no longer be firmly held.
>
> Magnus (Bot. Centr. 37, 289) holds it as incorrect to form such names as *Puccinia poculiformis* Jacq. Wettst. for *Puccinia graminis* Pers. Doctor Wettstein, when he made the change (Pilz flora der Steiermark, p. 18), said, "Although it is hard to drop a name as old as *Puccinia graminis*, I feel compelled to do it. There is no doubt that Jacquin described the æcidium of this species in 1786. The species name, 'poculiforme,' under which Jacquin described this æcidium as a *Lycoperdon*, is consequently the oldest name, certainly older than Persoon's of 1797 (in Tent. Dispos. Meth. Fung., p. 39)."

Arthur and Holway describe the stem rust under the name *Puccinia poculiformis* (Jacq.) Wettst., as follows:

HOSTS:

Æcidial, *Berberis vulgaris*.

Uredo } stages occur on { *Avena sativa* (cultivated oats),
Teleuto } { *Avena fatua* (wild oats),
and on the other cereals, as well as many grasses.

I.—Æcidia: On more or less thickened and discolored spots, usually in small groups, but when upon growing lateral shoots often covering large areas; margin prominent, white, erect, more or less jagged; æcidiospores, orange-yellow, becoming pale yellow after long drying, isodiametric, polygonal, 14-24*u* in diameter; wall rather thin, smooth, or sometimes rugulose, especially on one side.

II.—Uredospore: Sori large, oblong to linear, on both leaf surfaces, either scattered or confluent into rather large, definite groups, more usually found on the leaf sheaths; soon naked, ruptured epidermis prominent, ferruginous; uredospores elliptic, oblong or obovate, often somewhat constricted in the middle, 19-38 x 14-22*u*, brownish-yellow when fresh, becoming yellow on drying, echinulate; pores usually four, equatorial.

III. Teleutospore: Sori sparingly on leaf blades, more commonly on sheaths, culms and inflorescence, linear, often confluent, black, early naked, ruptured epidermis noticeable; teleutospores oblong fusiform, oblong cuneiform or narrow obovate, 75-60 x 12-22*u*, golden brown, smooth, somewhat constricted in the middle; apex darker colored, considerably thickened, obtuse or rounded; base narrowed; pedicel usually barely as long as the spore, colored like the spore.

Among the most common of rusts. Much less common on leaf *blades* than other species, but frequently seen on culms and sheaths, forming conspicuous black, effused patches. The form of the uredospores, number and arrangement of pores are characteristic, as is the brownish color, quite unlike the clear orange-yellow of those of the leaf and crown rusts.

Carleton (5) reports as follows on his observations and culture work with the stem **rust of oats:**

Physiological Relations. The uredo sori of the stem rust on oats are longer, larger and seemingly a little darker (than those of the stem rust of wheat), and usually there is proportionally more of the uredo present (on oats).

Inoculation Experiments. Successful infection was secured on—

Oats:
- Siberian.
- Black Tartarian.
- Amurskii.
- Dun.
- Nackter Kleiner Fahnen.
- *Avena fatua.*
- Tardeva denese.
- *Avena pratensis.*
- *Fenton's* rustproof.
- Ligowa.
- *Avena sterilis.*
- *Avena hookeri.*

Grasses:
- *Hordeum murinum.*
- *Dactylis glomerata.*
- *Koeleria cristata.*
- *Arrhenatherum elatius.*
- *Trisetum subspicatum.*
- *Alopecurus alpestris.*
- *Holcus mollis.*
- *Agrostis scabra.*
- *Polypogan monspeliensis.*
- *Festuca sp.*
- *Eatonia sp.*
- *Ammophila arenaria.*
- *Phleum asperum.*
- *Bromus ciliatus.*

The following hosts are listed as authentic:
- *Avena sativa patula.*
- *Avena sativa orientalis.*
- *Avena sativa nuda.*
- *Dactylis glomerata.*
- *Arrhenatherum elatius.*

Probable hosts:
- *Avena fatua.*
- *Avena hookeri.*
- *Avena pratensis.*
- *Avena sterilis.*
- *Kolleria cristata.*
- *Lolium perenne.*

Occurrence and Distribution. The black stem rust of oats is certainly more common than the black stem rust of wheat. However, it is not known whether the stem rust of oats is generally commoner than the crown rust, although definite statements on this point might be made in the case of certain localities, locality apparently being an important feature in this connection.

As in the case of stem rust of wheat, the form on oats is not constant in appearance, although perhaps more so than the former. Reports indicate that it is not so common in the Southern states as in the Northern, the crown rust being in the Southern states the more common. Stem rust was not seen in Maryland during two years' work there. Straw examined in Texas revealed *only* the presence of the *crown rust* teleutospores.

So far as known, the stem rust of oats does not winter its uredo in the United States.

Damage. The damage which this rust causes to oats in the United States is even greater than that produced by the form on wheat. Almost every year thousands of acres are totally destroyed in some portion of the country by this rust, the damage being greatest north of 37° North latitude and east of 95° west longitude. Eriksson reports it as very destructive in Sweden.

Clinton (9) reports on the stem rust of oats as follows:

This rust produces elongated outbreaks on the stems and leaf sheaths. These are at first the reddish uredo stage but later the black teleuto stage. The stems are weakened by the attacks of the fungus, and badly rusted grain is apt to lodge. The barberry is the host for the æcidial stage, but apparently the fungus often skips this step in its life cycle.

This rust very commonly occurs *with* crown rust and the injury they cause to the crop of oats is sometimes considerable. Very little can be done to lessen these troubles.

Smith (44) writes as follows regarding the stem rust of oats as found in California:

Produces numerous pustules of the black or red rust on the surface of the plants, sometimes covering the leaves with the reddish, powdery spores. Sometimes abundant in wet seasons, badly injuring the crop.

No treatment is feasible save the use of resistant varieties.

Davis (11) reports *Puccinia graminis* Pers. (both uredospore and teleutospore stages) on oats in Wisconsin, 1914.

Howitt and Stone (27) report the stem rust present in Ontario, and describe its appearance and the injury caused. They write as follows concerning the barberry stage of the rust:

> The barberry is not necessary for the continuance of stem rust, for it may have several other ways of passing the winter:
>
> 1. Wintering of the uredospore.
> 2. Wintering of the mycelium in winter grain, or volunteer grain plants, or on wild-grass hosts.
> 3. Wind distribution of spores from the South.
> 4. Rust *in* the seed.
>
> The barberry *does* increase the severity of stem rust, and may act as a reinvigorator of the fungus.
>
> BARBERRY IN ONTARIO. There are several species; *Berberis vulgaris* is most frequently found. This species and its purple-leaved variety both harbor the stem rust, and it is now contrary to law to plant them in Ontario. (Copy of the "barberry act" appended to their publication.)
>
> The Japanese barberry (*Berberis thunbergii*) may be planted, as this species does not harbor the rust.
>
> Conditions favoring rust are said to be:
>
> 1. Cool, damp weather at heading time.
> 2. Poorly drained land.
> 3. Fields so situated that air drainage is poor.
>
> Suggested means of (partial) control are:
>
> 1. Destroy all *Berberis vulgaris.*
> 2. Well-drained fields.
> 3. Early maturity secured by early seeding in a well-prepared seed bed.
> 4. Choice of high-yielding varieties and of those not badly injured by rust.
> 5. Use pure seed of only one variety, to insure even ripening.
> 6. Treat all seed for smut, as plants infected with smut are very subject to rust.
> 7. Sow only sound, plump grain.
> 8. Use barnyard manure or other nitrogenous fertilizers *with care,* as they may produce a rank growth, which invites rust.
> 9. Field management: Crop rotation, proper manuring, thorough tillage, eradication of weeds and wild grasses, etc.

Taylor (48) writes as follows on the rust of oats in New Hampshire:

> The fungus attacks leaves and stems at time of heading, or sometimes several weeks earlier. The disease weakens the vitality of the plant to such an extent that it fails to produce seed and frequently breaks down and dies.
>
> In some sections of the state the rust is unquestionably the worst pest of oats. Although its depredations are somewhat periodic, being more disastrous some years than others, the most destructive attacks come in seasons of unusual moisture and warmth during the month of June, which induces the oats to make a large, quick growth. Whether the quick, succulent growth renders the plant more susceptible to the attacks of the fungus, or whether the stated weather conditions are more congenial for the growth of the fungus, the writer is unable to say. Perhaps both premises maintain.
>
> The time of seeding also seems to have an appreciable effect upon the extent of rust. The writer has frequently observed that early-sown fields of oats have suffered less from rust than late-sown ones.
>
> In 1906, in order to get some data on this question, a series of small plats were seeded to Welcome oats at intervals of one week, April 20 to June 8.

Results are shown in the following table:

Date of seeding.	*Date of ripening.*	*Amount of rust.*
April 20	Aug. 3	None.
April 27	Aug. 8	None.
May 4	Aug. 13	Slight.
May 11	Aug. 14	Slight.
May 18	Aug. 19	Considerable.
May 25	Aug. 22	Much.
June 1	Aug. 26	Much.
June 8	Sept. 6	Very bad.

Zavitz (52) published the following data on thickness of seeding as a factor influencing rust in oats. The kind of rust is not mentioned.

THICKNESS OF SEEDING OATS, ONTARIO AGRICULTURAL COLLEGE.

AVERAGE RESULTS FOR FOUR YEARS.

Inches between plants.	Seed per acre.		Heads per plant.	Per cent of heads per acre.	Plant height, inches.	Per cent lodged.	Per cent rust.	Days to mature.	Pounds per bushel.	Yield per acre.	
	Pounds.	Bushels.								Straw, tons.	Grain, bushels.
1	414.4	12.34	1.0	100	20.4	5.6	11.8	91	25.0	1.75	30.60
2	104.0	3.06	1.1	31	27.8	11.9	15.0	93	31.4	1.58	34.95
3	46.1	1.36	1.3	17	32.6	12.8	17.8	94	33.2	1.52	41.73
4	26.0	.76	2.0	13	33.1	29.9	20.9	95	31.5	1.29	38.99
6	11.6	.34	4.2	12	35.3	35.8	25.4	97	28.6	1.40	37.42
8	6.5	.19	6.5	11	34.9	34.7	27.7	99	26.4	1.20	31.77
12	2.9	.09	11.2	9	34.9	30.1	33.2	100	23.9	1.03	21.93

The average results of the per cent of rust are very interesting, as they show a gradual increase in amount of rust on the straw of the oats from the thickest to the thinnest seedings. The plants from the thin seeding had about three times as much rust as those from the thick seeding. The amount of rust on the plants which were four inches apart was about the average of that of the thinnest and the thickest seedings.

Newton (39) as early as 1871 had recorded results which led him to draw similar conclusions to those of Zavitz, *e. g.,* that plants closely spaced (from heavy seeding) were less rusted than those having more space (from light seeding). Newton gives the following account of his observations:

> I have observed that oats standing very thinly on the ground are several days later in ripening, and are much more liable to be injured by rust than those that are thickly sown. I have raised them in drills and have seen them raised in this way, and in nearly every case they were more or less affected by the rust and were from one to two weeks later than those sown in the usual manner, and in some cases were so badly rusted as not to ripen at all.
>
> On one strip about two feet in width at the side of the field only a small quantity of seed was scattered, probably not one-fourth as much as on the land adjoining. At the time of cutting them, the oats that were thickly sown were ripe, the straw bright and clean, showing no signs of rust, while those on this small piece were perfectly green and very badly rusted. Most of the field was sown at the rate of three and one-half bushels per acre.
>
> To test the question of thick and thin seeding, a small part of the field was sown at the rate of two bushels per acre. On this piece the oats were two or three days later than on the rest of the field and showed signs of rust, but were not materially injured by it. The result of my observations is that oats that are thickly sown are much less liable to be injured by rust, that they ripen earlier, and that the straw is brighter and of better quality than when only a small quantity of seed is used. This liability to rust is one great objection to very thin seeding.

Fraser (19) reports stem rust is usually common on oats grown at the farm of Quebec Agricultural College.

Freeman and Johnson (20) write as follows concerning the distribution of oat stem rust:

> In the southern states of the eastern half of the United States—that is, south of and including Tennessee and North Carolina—rust of certain cereals has been so serious as almost to prohibit the growing of them in those regions. It is very difficult, for instance, to grow spring oats profitably in portions of the southernmost tier of states east of the Mississippi river, one of the chief difficulties being rust. Winter oats are the only cereal grown extensively in this area.

Regarding damage, these authors are of the opinion that:

> The stem rust of oats, if not more harmful, is fully as destructive as the similar form on wheat, and its distribution is somewhat similar.
>
> Much of the real damage caused by stem rust results from the severe infections of it which sometimes occur on the spikelets and spikelet stems.

Concerning the specialization of this rust they write as follows:

> The oat rust is the most closely specialized of the biologic forms of *P. graminis* on the small grains, but in its ability to infect the other species under rarely occurring conditions still shows its close affinity to the other rusts.
>
> Of all the stem rusts on the small grains, that of oats is the most distinctive and individualistic in appearance, having larger pustules of uredospores, which are formed very commonly both on stems and leaves (as in barley), in sharp contrast with the more restricted location of the pustules in the stem rusts of wheat and rye.
>
> As a biologic form, the stem rust of oats may be said to be generally confined to oats. It can at times be carried to barley, but never produces large or vigorous pustules. It is only rarely that transfers to wheat and rye can be made.

Stakman (45) reports as follows on his experiments with *Puccinia graminis avenæ:*

> GENERAL STATEMENT.
>
> This rust in this country is supposed to infect no cereal except oats, although it is capable of infecting a number of grasses. Carleton was unable to transfer it to wheat, barley or rye. Eriksson mentions it as being found on oats and eighteen species of grass in Sweden. Freeman and Johnson, however, find that it can be transferred to barley also, and they report that Derr succeeded in obtaining direct transfers from oats to wheat and rye.

CONCLUSIONS FROM INOCULATION RESULTS ON RYE.

The stem rust of oats can be transferred directly to rye. This was accomplished most easily when the plants were grown in heavily manured soil. Exposing them to various anæsthetics before inoculation seems to increase the virulence of infection slightly, while leaf injury had no apparent effect. In the various trials under different conditions, 27 out of 236 leaves developed pustles and 73 were flecked. Under conditions which might exist in the field, 12 out of 73 leaves produced pustules and 22 were flecked.

INOCULATIONS ON WHEAT.

The stem rust of oats can be transferred to wheat only with great difficulty. Carleton did not succeed in obtaining infection in his experiments; Freeman and Johnson made 100 inoculations, but none was successful. They report, however, that Derr was able to make transfers.

Summary of Inoculation on Wheat. Out of a total number of 283 leaves inoculated under varying conditions, only 4 developed pustules and 113 became flecked, showing that although the rust of oats can sometimes develop on wheat, it can seldom attain to pustule formation. The severity of infection, always slight, can be increased somewhat by exposing plants to be inoculated to anæsthetics. The experiment with high fertilization of soil seems to indicate that here, as well as in the case of rye inoculated with oat rust, the mycelium is enabled to develop more extensively and possibly produce more spores than when ordinary soil is used.

Fife wheat (Minn. No. 163) was inoculated with stem rust of oats, and it was found that only a few host cells were involved. The contest between host and parasite is short and decisive, the hyphæ seldom developing sufficiently to give any external evidence that the germ tube has even entered. This extreme case of immunity seems to differ in degree only from those conditions presented by resistant varieties.

INOCULATIONS ON BARLEY.

The results of this series of inoculations were very similar to those obtained by other investigators. The behavior of the rust was typical of its usual behavior on an uncongenial host plant. The flecks were small in nearly all cases, and were especially sharp when plants had been exposed to anæsthetics. Only one leaf out of 147 inoculated under varying conditions was pustuled. Flecks were formed on 32.

GENERAL SUMMARY.

The stem rust of oats can be transferred successfully from oats to any one of the other cereals. It infects rye much more easily than wheat or barley. Anæsthetics help to break down the barriers, as does a high degree of soil fertilization. It should be mentioned that this fact seems due, not to any new ability the rust fungus has of attacking an uncongenial host, but to an increased capacity for development. Here again evidence of the possible nature of resistance is offered by the inoculated plants. The flecks, whether large or small, consist in many cases of dead tissue of the host plant. Histological examination shows that the fungus gains entrance but cannot develop to any extent in these areas which are killed by the fungus itself.

Stakman and Piemeisel (46), from their studies of the biologic forms in the stem rusts, give the following list of hosts for the stem rusts of oats:

P. Graminis avenæ Erikss. and Henn.

- Oats (*Avena sativa*).
- *Avena fatua.*
- *Avena elatior.*
- *Anthoxanthum odoratum.*
- *Holcus lanatus.*
- *Phalaris canariensis.*
- *Koeleria cristata.*
- *Dactylis glomerata.*
- *Bromus tectorum.*

They found also that this form has quite consistently weakly infected the following:

Barley.
Elymus canadensis.
Lolium italicum.
Lolium perenne.
Festuca elatior.

The salient points of the life history of stem rust are here summarized:

SPORE FORMS.

0. Spermogonia first appear in spring on the upper surface of barberry leaves.

I. Within a short time the æcidial or cluster cups are evident on the lower surface, and their yellow spores soon are liberated, and if blown to an oat leaf or stem, there cause infection.

II. In eight to twelve days (or more in cool weather) the fungus growth (mycelium) so formed within the oat plant will give rise to a number of uredospore sori. These may first be seen as light, yellowish-green flecks, but soon the epidermis is ruptured and the dark-reddish uredospores are dispersed. The uredo-sori are large, longer than broad, and often confluent, forming great linear patches of rusted tissue. The epidermis is torn open early, and the sori are typically erumpent, and are not scattered as in the case of the crown rust.

The uredospores are not typically nearly circular in outline as in the crown rust, but are ellipsoidal. They are of a dark reddish-brown color, not bright yellow as in the crown rust, and have (usually) four equatorial germ pores.

III. Towards harvest time the black-rust stage gradually replaces the uredo, and the teleutospores are formed in the same or similar sori. They too rupture the epidermis early and form linear dark-brown to black, erumpent pustules.

The teleutospores are clavate, thick-walled (especially thickened at the apex), and the tip of the apical cell is rounded, blunt, or unevenly tipped, but not provided with the finger-form projections which form the "crown," so characteristic of those of the crown rust.

The teleutospores will only germinate after a winter's rest, when the typical four-celled promycelium is formed, and from each of these cells a branch is sent out, bearing a sporidium. These in turn, if blown to a barberry leaf, will enter and cause infection, thus completing the life cycle.

NOTES ON THE DISTRIBUTION OF OAT RUSTS IN THE UNITED STATES.

The following brief observations are from Carleton (5):

CALIFORNIA. Reports indicate that rust does not commonly injure the grain, still in some places *oats* are severely damaged. Losses are confined almost wholly to the coast districts.

It is claimed black oats are more resistant than white.

GEORGIA. In this state, as in all the Gulf states, oats are seldom injured by rust. Texas Rustproof is the variety commonly grown.

ILLINOIS. Oats are commonly and often seriously damaged by rust.

INDIANA. Oats are commonly damaged by rust. Late varieties are invariably much more liable to rust than the early ones. In some instances the growing of oats has been abandoned on account of rust. Grain is said to be free from rust in the warm, sandy soils. Some claim rust is very severe only once in two to five years. Black stem rust is the most injurious species.

IOWA. Rust often destroys the oat crop. It is always the black stem rust that is particularly injurious.

KANSAS. Oats are often greatly damaged by stem rust in the eastern portion, and are sometimes a total loss. The crop suffered greatly in 1893. Occasionally fields of late-sown oats are entirely destroyed before harvest.

KENTUCKY. Oats are extensively injured.

MARYLAND. During 1895 and 1896 there was seen an abundance of crown rust of oats, but it did not appear to cause any particular damage. Black stem rust was not observed. Much oat rust has been reported from Cecil county.

MICHIGAN. Oats suffer more than wheat from rust. Rust rarely occurs in the sandy districts.

MINNESOTA. In certain years oats are greatly injured. White Russian oats are said by some to be rust resistant.

MISSOURI. There is considerable rust here, but not much is known concerning the relative proportions of the leaf and stem rusts. Oats are often much injured.

NEBRASKA. In the eastern portion of the state oats are often severely damaged.

NEW YORK. Oats are often injured, especially in Erie and Wyoming counties.

NORTH DAKOTA. Oats are often injured. White Russian oats are thought to be somewhat rust resistant.

OHIO. Black stem rust is occasionally very prevalent, and there is much more injury to oats than to wheat.

OREGON. Cereal rusts cause only slight damage as a rule. Occasionally oats are considerably affected by the crown rust, as in Sherman county in 1892.

PENNSYLVANIA. Oats are very commonly injured. (Much of the damage may, however, be due to the red leaf-blight disease.) Fertilizers are supposed to materially aid the grain to escape rust, by causing rapid growth and early maturity. Rust is always worse in the lowlands.

SOUTH DAKOTA. Oats, especially when planted late, are often badly rusted.

TENNESSEE. Little injury is done to oats.

TEXAS. Oats are seldom injured to any extent.

VIRGINIA. Oats (in the Shenandoah valley) are damaged quite often. The rust is most abundant in the lowlands.

WISCONSIN. *It is claimed by some that White Russian oats possess a considerable degree of resistance.* Black stem rust constitutes a good proportion.

The following notes on the distribution of oat rusts are from the records of the Plant Disease Survey of the United States Department of Agriculture.

They are in most cases from the annual reports sent in by the plant pathologists of the state experiment stations:

Alabama. Prof. F. A. Wolf reported the crown rust in 1912.

In 1915 both crown and stem rust were reported as common in the state, causing a loss estimated at 5 per cent.

Arkansas. In 1907 the crown rust was reported by Prof. W. M. Scott.

California. E. C. Johnson reported the crown rust in 1911.

Delaware. Prof. M. T. Cook reported stem rust of oats as worse in 1910 than in 1909. In 1907 crown rust reported as occasional. In 1908 crown rust possibly less severe than in 1907. In 1909 crown rust about as in 1908. In 1910 crown rust worse than in 1909. In 1911 crown rust less than in 1909. In 1912 crown rust reported. In 1913 crown rust reported. In 1915 crown rust common; injury 5 per cent.

Georgia. Crown rust reported by E. C. Johnson in 1911.

In 1913 Prof. A. C. Lewis reported more than the normal amount of oat rust (more than in 1912). Present in 50 per cent of the fields; estimated loss, $5,000. Very injurious in some fields.

The oat crop was much more affected with rust this season than usual. The fields, though, that had the best preparation and were well fertilized suffered least from rust. We could not see any marked difference between the different varieties of oats, such as Bancroft and Texas Rustproof.

Idaho. Prof. C. E. Temple reported in 1913 that stem rust was very prevalent; 2 to 5 per cent of the crop injured in north Idaho.

Illinois. In 1911 Prof. J. T. Barrett reported that very little stem rust was noted.

In 1911 Professor Barrett reported the crown rust was more than usually prevalent.

In 1912 as severe on late oats, little on early.

Indiana. In 1904 Dr. J. C. Arthur reported rust on oats to have done little or no damage; the oat crop was very heavy.

In 1905 Dr. J. C. Arthur estimated a loss of 3 per cent from stem rust. The reports were all from the southern counties. Observations in the northern part of the state indicate that the oat crop was unusually free from rust this year.

In 1906 Doctor Arthur reported 3 per cent of crop injured, less than in 1905, and weather not favorable.

In 1907 Prof. F. D. Kern wrote as follows: "It is impossible to say which rust is meant in the reports on oats, and further the unfavorable weather caused a disease or physiological disturbance which many mistook for rust."

Oat rust was reported by Prof. F. D. Kern in 1910 and 1912.

In 1908 Prof. F. D. Kern reported an estimated loss from crown rust of 20 per cent. In 1909 crown rust reported. In 1911 crown rust reported as normal amount. In 1913 crown rust reported. In 1914 crown rust reported from several counties. In 1915 crown rust reported from all over state.

Iowa. Dr. L. H. Pammel reported stem rust as bad in many counties in 1904.

In 1905 Dr. L. H. Pammel reported oat rust as not so prevalent as in 1904, loss being less than 3 per cent. Earliest report, June 15. Weather conditions not favorable—cold nights and cool rains. Reported as severe in ten counties; reported as some damage in thirty-two counties; reported as no damage in one county.

In 1906 the stem rust was less than in 1905; only 1 per cent of the crop injured. Earliest report June 20. Weather conditions not favorable—cool weather. Rust did little damage in state except in northwestern part, where one man reported a loss of 60 per cent. Late oats are more rusted than early. Both species of rust equally common.

In 1907 Doctor Pammel reported there was more stem rust than in 1906; 50 per cent of crop was injured. Earliest report, June 21. Weather was favorable—rain and warm weather late June and early July. All varieties were badly rusted, the earliest (such as Early Champion) the least. Some of Norton's hybrids and Clydesdale were badly rusted. Some reports read, "oats red with rust." Much of oats averaged only 16 pounds per bushel. All sections of the state report less than one-half crop, and in Story county one-fourth crop.

In 1908 Doctor Pammel reported as follows: "Oats were comparatively free in some places, especially the early varieties, and on high ground. In low places the stem rust was rather bad. The northern sections of the state suffered more than the southern. Yield and weight per bushel were better than in 1907. Stem rust was quite prevalent, injuring 25 per cent. Weather was favorable for rust—too much rain, not enough sun. Stem rust was not as severe as in 1907, and there was a better crop."

In 1909 stem rust was reported as common; 5 per cent injury, less than in 1908; favorable weather.

In 1910 stem rust was not abundant; 2 per cent injury; earliest report, June 25; weather unfavorable.

In 1911 stem rust was not common; 1 per cent injury; weather unfavorable.

In 1912 injury was 2 to 5 per cent; more rust on low than on high ground. Stem rust occurs in every county of the state.

In 1913 stem rust was reported as common, but not serious this year; weather favorable.

In 1914 not so much stem rust as in wet years; earliest reports, June 15.

In 1915 stem rust abundant in some sections.

Doctor Pammel reports on crown rust as follows:

"Occurred in 1904, 1906 and 1907. In 1908 estimated injury was 25 per cent. Weather favorable—too much moisture—but better crop than in 1907. No resistant varieties.

"In 1909 crown rust was common; 5 per cent injury. Less rust than in 1908; larger yield, heavier oats.

"In 1910 crown rust was not abundant; 2 per cent injury. Earliest reports, June 25 to July 8. Weather unfavorable. Little rust on early-maturing varieties, as Early Champion. The best crop of oats for several years.

"In 1912 crown rust reported, but weather unfavorable.

"In 1913 weather was unfavorable. Oat crop excellent in some places; other places light, due to unfavorable weather at seeding time. Crown rust is widely distributed; did some damage; more in northern than in southern Iowa.

"1914, crown rust not so abundant as in wet years. Earliest report, June 15."

KANSAS. Oat rust reported by E. C. Johnson in 1911.

In 1914 L. E. Melchers reported stem rust as quite prevalent at Hays. Earliest reports, June 17.

In 1915 crown rust was reported from Miami and Thomas counties. Earliest report, July 16.

Louisiana. In 1907 Prof. H. R. Fulton reported the prevalence of crown rust as about the same as usual.

In 1908 injury from crown rust was very general and the estimated loss considerable. Earliest report on May 9.

E. C. Johnson observed rust on oats in 1911. In 1911 Prof. C. W. Edgerton reported crown rust as very common; estimated loss considerable; first appearance in April.

In 1912, 1913 and 1914 crown rust was again reported as very common; estimated loss considerable. Also 1915; first appearance in April.

Maine. In 1908 Prof. W. J. Morse reported that "apparently both the stem and crown rust are present." Neither is severe enough to cause alarm to the grower, but rust is common and widely distributed in the state.

In 1912 Prof. C. E. Lewis reported more stem rust than in 1911. Weather favorable—much moisture and many cloudy days. Stem rust causes much damage, especially to late seeded oats.

Maryland. Prof. J. B. S. Norton reported on oat rust as follows: In 1903, very destructive; in 1907, abundant; in 1908, less than usual; in 1909, none seen.

Never seen on winter oats. Some volunteer oats (in summer) are badly rusted. In 1915 rust was reported.

Massachusetts. Prof. G. E. Stone reported oat rust as being unusually prevalent in 1906, with rather heavy losses. Weather conditions were favorable; more injury from rust than for many years.

In 1915 stem rust was reported as frequent, and crown rust seen only at Amherst.

Michigan. In 1907 Prof. B. O. Longyear reported crown rust as plentiful on fall oats in an orchard during September and October.

Minnesota. In 1907 Dr. E. M. Freeman reported stem rust as quite severe throughout the Mississippi valley, causing considerable damage. The light oat crop was, however, not due entirely to this rust; other diseases (including the crown rust) and the green bug were also important factors. In the northern part of the valley the larger part of the damage was done by the stem and crown rusts.

In 1908 Doctor Freeman reported stem rust as quite serious throughout the state, but occurrence spotted as in wheat. Was very serious in some parts of the state.

In 1909 there was less stem rust than in 1908, as weather conditions were not favorable (dry July). This rust is common every year. Losses this year were local, due to low ground or wet location. Found usually together with the crown rust. Æcidial stage on barberry shrubs probably more abundant than usual.

In 1911 there was much more stem rust than usual; estimated loss, $1,000,000. Earliest report in June.

In 1912 stem rust generally distributed; estimated loss, $500,000. Earliest report, June 6.

In 1913 quite generally distributed, less than usual. Earliest report in June. Estimated loss, $350,000.

In 1905 Prof. C. P. Bull reported "the usual amount" of crown rust, slight injury and loss; earliest report in May; weather conditions were favorable, *i. e.,* a wet season. Crown rust is always present, but appears to do but little damage; heavy yields are secured from badly infected fields.

In 1907 Doctor Freeman reported crown rust as very common; almost always associated with stem rust.

In 1908 Doctor Freeman reported crown rust occurring about as in the case of stem rust, causing considerable damage. As usual, the two rusts work together.

In 1909 the losses from crown rust were local; unfavorable weather for the rust—dry in July. This rust is common every year, and it *with* the stem rust probably causes the greatest loss of any cereal rust.

Oat rusts are especially bad in the northeastern part of the state. Local losses occur even in dry years. Resistant varieties are not known, though early varieties more often escape than late varieties. The æcidial stage is exceedingly common on cultivated and wild buckthorns all over the state.

The following notes on the distribution and occurrence of oat rusts in Minnesota were obtained during the summer of 1915 by Mr. J. R. Holbert, then in the employ of the Bureau of Plant Industry, in coöperation with the Minnesota Agricultural Experiment Station. In practically every field the crown rust was present in amounts ranging from a "trace" to 40 per cent or more, but apparently without causing severe damage to the crop.

On the other hand, there were only a few fields which had an appreciable amount of stem rust, but in at least one of these the note indicates damage to the crop, which appeared stunted. We must conclude, then, that in this locality and at least during the season of 1915, the crown rust was much more commonly present than the stem rust, and in some fields in amounts almost constituting an epidemic. It may even be said that stem rust was here rarely met with.

Report of the cereal-disease trip in Carver, Hennepin, McLeod, and Meeker counties. (July 15, 1915.) There were traces of leaf rust in every field, and occasionally a trace of stem rust.

Report for Goodhue county. There was no stem rust on oats in this county. At places, however, the leaf-rust infection was very high.

Report for Wabasha county—Wabasha. (Observations made July 19.) Stem rust was observed in one field of oats. The infection was about 10 per cent, and, since the straw was lodged badly and the growth very rank, it is probable that stem rust caused some loss in this field. In this same field there was a 25 per cent infection of crown rust.

In an adjacent field the oats contained only a trace of leaf rust.

Report for Wabasha county—Millville, Plainview. (Observations made July 20 and 21.) Oats: Although there was considerable crown rust, the crop was entirely free from stem rust.

Report of Olmstead county. (Observations made July 22, 1915.) There was a trace of crown rust in every field. The oats in one contained a trace of stem rust.

Report for Dodge county. (Observations made July 23, 1915.) There was a trace of stem rust in one field and a rather heavy infection of crown rust in many fields.

Report for Waseca county. (Observations made July 24, 1915.) Only one field of oats contained a trace of stem rust. At no place was there more than a 10 per cent infection of crown rust.

Report for Blue Earth county. (Observations made July 26, 1915.) The oats were free from stem rust with the exception of a trace in one field. Crown rust was generally distributed—about a 25 per cent infection.

Report for Watonwan county. (Observations made July 27 and 28.) There were traces of stem rust in several places. Crown-rust infections were rather high at times—40 to 65 per cent.

Report for Redwood county. (Observations made July 29, 1915.) The crown-rust infection was generally heavy—40 to 60 per cent. Stem rust was observed only in traces.

Report for the vicinty of Tracy, Lyon county. (Observations made July 30, 1915.) Generally the oats were comparatively disease free. There were traces of stem rust and a heavy infection of crown rust.

Report for Lyon county. (Observations made July 31, 1915.) There were traces of stem rust in several fields of oats, and a little less than the usual amount of crown rust.

Vicinity of Ortonville, Big Stone county, Minn. (Observations made August 3, 1915.) Most of the oats contained some stem rust. In one field the infection was 10 per cent. The rust pustules were long. Around each the tissue was turning a reddish-blue color. The uredospores were much browner than those of stem rust usually are. The whole field presented a very stunted appearance.

Report for Stevens county. (Observations made August 4, 1915.) The oats, though comparatively free from rust, were rather poor in quality.

Report for Pope county. (Observations made August 5, 1915.) Little stem rust was found. In two fields the crown rust infection reached 60 per cent.

Report for Grant county. (Observations made August 6, 1915.) Only traces of stem rust were found in the oats. The usual amount of crown rust was present.

Report for Wilkin county. (Observations made August 7, 1915.) Some of the oats were slightly infected with stem rust.

Report for Ottertail county. (Observations made August 9, 1915.) Oats were practically free from stem rust so far as damage was concerned.

Report for Wadena county. (Observations made August 10, 1915.) The oats, though not promising as heavy yields as some of those in Ottertail county, were very clean and of a pure variety (White Russian). There was no stem rust; only traces of crown rust, for the most part.

Report for Becker county. (Observations made August 11, 1915.) Oats were troubled very little with disease.

Report for Clay county. (Observations made August 12, 1915.) The oats were not badly rusted, there being only traces of stem rust and 10 per cent leaf rust.

Report for Norman county. (Observations made August 13, 1915.) With the exception of one field, the oats were practically free from disease. However, this one field contained 3 per cent of stem rust.

Report for Marshall county. (Observations made August 16, 1915.) Very little rust was observed on oats.

Report for Kittson county. (Observations made August 17, 1915.) Conditions in Kittson county were similar to those in Marshall county.

Such detailed figures as these, when obtained by experienced men, are much more useful than the scattered observations usually available. Could such a rust survey be made each season in the important oat-producing states for a ten-year period our true understanding of the problem would be greatly increased.

NEBRASKA. In 1903 Dr. C. E. Bessey reported oat rust as generally rather abundant and causing considerable damage. In some places it was very destructive.

In 1904 Doctor Bessey reported the occurrence of oat rust, in some cases producing a loss estimated as high as 50 per cent. Area affected is practically the same as that for wheat rust.

In 1905 Prof. F. D. Heald received report of the occurrence of oat rust in eight counties.

In 1906 crown rust reported as about the same as in 1905—5 to 50 per cent of the crop injured.

In 1907 crown rust was reported from six counties and stem rust from only one.

In 1909 Prof. E. M. Wilcox reported oat rust at Lincoln.

In 1911 Prof. E. M. Wilcox reported exceptionally severe attacks of the crown rust in western Nebraska, culms badly diseased.

NEW JERSEY. Stem rust reported as common in 1913. Crown rust reported by Prof. M. T. Cook in 1913 and as common in 1914.

In 1915 crown rust reported as common over the entire state. Stem rust in 1915 reported as only occasional.

NEW YORK. In 1903 Professor Whetzel reported both crown and stem rust as very common.

In 1911 E. C. Johnson reported the occurrence of oat rust.

In 1913 Prof. M. F. Barrus reported stem rust as common in five counties.

In 1914, stem rust not as abundant as last year; only slight injury.

In 1915 stem rust was reported as generally prevalent, but not bad. Earliest report, July 25.

NORTH CAROLINA. Prof. F. L. Stevens reported in 1905 that oat rust was about as prevalent in that year as the one previous; estimated loss 10 to 20 per cent.

Prof. H. R. Fulton in 1912 reported crown rust as causing slight financial loss. It developed late.

In 1913 crown rust was more prevalent than usual; caused slight financial loss.

In 1914 crown rust about as prevalent as usual, causing slight financial loss.

NORTH DAKOTA. In 1907 Prof. H. L. Bolley reported as follows: "Oat rust occasioned apparently little loss, but in my opinion the rust reduces the weight of grain more than is supposed, especially in wet regions. Several farmers report the rust more destructive on rich land."

In 1908 Professor Bolley reported relative prevalence of stem rust as low; only 2 to 3 per cent injury. Earliest reports, July 4 to 15. Most damage in late oats.

OHIO. In 1904 oat rust thrived.

In 1905 less than in 1904; 18 per cent of crop injured. Estimated loss, $360,520. Crop of much importance in the state. Earliest report, May. Weather was favorable—prolonged moisture. No rust-proof sorts as yet.

In 1906 oat rust about as prevalent as in 1905. Reported from sixteen counties. Negative reports from five counties. Eleven per cent of crop injured, in most severe case 50 per cent. Estimated loss, $350,000. Earliest report, June 1. Weather conditions favorable.

In 1907 Prof. A. D. Selby had reports of oat rust from two counties. Weather was cold. Injury was overshadowed by that caused by leaf blight.

In 1908 Professor Selby reported crown rust as more prevalent than usual. Reported from three counties; a large (estimated) loss. Earliest report, July 29. Weather was favorable for the rust; plants were checked by other troubles. Planting was done very late.

In 1909 there was less crown rust than in 1908; it was reported from four counties.

In 1910 crown rust was reported from one county. Earliest report in July.

In 1911 crown rust reported from four counties. Stem rust was reported from two counties.

In 1912 crown rust reported from one county. Stem rust was reported from five counties.

OKLAHOMA. In 1915 crown rust (listed as *Puccinia rubigo-vera*) quite common. Earliest report, March 30.

In 1915 stem rust reported as common, 1 to 50 per cent loss. Earliest report in April. Bad in some localities.

PENNSYLVANIA. Prof. H. R. Fulton in 1908 reports 5 per cent of crop injured by oat rust. Earliest reports in May.

In 1908 stem rust is reported to have injured 15 per cent of the crop. Estimated loss, 5 per cent. Early oats escaped injury. Earliest report, June 15.

In 1909 Prof. H. R. Fulton reported crown rust more prevalent than usual. Fifteen per cent of the crop injured. Estimated loss, 5 per cent. Earliest report, June 1.

Crown rust also reported in 1910.

In 1911 crown rust first reported about June 10; less prevalent than usual. Estimated loss, 1 per cent.

Prof. C. R. Orton in 1913 reported crown rust as relatively more prevalent than usual. Twenty-five per cent of the crop was injured. Estimated loss, 5 per cent. Noticed rather early, during the wet weather in July.

SOUTH CAROLINA. Crown rust was reported in 1908.

In 1912 Prof. H. W. Barre stated that crown rust was only reported from one county. First appearance in October. In one field visited in November the disease was causing serious loss, which is the first time this has been observed in the fall.

Crown rust also reported in 1913.

SOUTH DAKOTA. In 1910 Prof. E. W. Olive reported the crown rust as common, but not serious. Weather conditions were unfavorable and the æcidial stage on *Rhamnus* was killed by early frosts, there being, consequently, but little *Rhamnus* infection.

In 1914 H. S. Coe reported stem rust of oats as bad; 30 per cent injury. Many fields (in Brookings county) entirely destroyed.

TENNESSEE. Prof. S. H. Essary reports oat rust (*Puccinia rubigo-vera*), probably meaning crown rust, collected at Knoxville in 1910 and also in four other counties in 1911.

Following is the 1915 report of W. T. Evans, collaborator, Cereal Disease Survey, made in coöperation with the Tennessee Agricultural Experiment Station:

Points visited: Dalton, Athens and Clarksville, all in northern Georgia, and representing the northwest, north central and eastern mountainous regions of the state; Cullman, Decatur, Tuscumbia and Huntsville, all in northern Alabama.

In Tennessee the following counties were visited: East: Roane, Knox, Hamilton. Middle: Coffee, White, Putnam, Smith, Warren, Wilson, Davidson. West: Madison, Woakley, Obion.

In Kentucky the counties visited were: Christian, Jefferson, Carrol, Owen, Fayette, Woodford.

The crown rust was the one mainly found on oats. Time of planting seemed to have been important in determining the amount of rust present in the various fields.

Berberis vulgaris (common barberry) was not seen except in a nursery at Louisville, Ky. It is probably grown as an ornamental shrub in the cities, though most hedges are of *Berberis thunbergii,* but does not occur wild in this section.

Rhamnus caroliniana occurs (wild) in Tennessee. Its (possible) relation to the crown rust of oats is not known. Other species of *Rhamnus* probably occur, at least in nurseries and as ornamentals in cities.

The infection of stem rust was not of long standing in any field, probably due to the unfavorable season. No data were secured as to the date of first appearance of rust.

In one field of oats the effect of late planting and subsequent weather conditions on the amount of crown rust was noted. Half the field was planted October 1, when rain delayed the work for ten days. That planted early had the higher infection of rust, and the growth was stunted. That planted later was slower in receiving infection, which did little harm to the plants.

There seems to be less rust this year than for many years. This is probably largely due to the fact that through April and up to about May 15 there was very little rain.

The stem rust was found in most localities, but in very small amounts, usually less than 1 per cent, and then mostly on low, wet land.

The crown rust was present in every oat field visited, the stem rust in only a few, at least in appreciable amount. Neither rust was recorded in epidemic proportions during the season of 1915.

TEXAS. In 1904 stem rust reported as bad.

E. C. Johnson in 1911 reported oat rust.

In 1915 crown rust reported. First appearance, April 19; period of most damage, mid-April.

VERMONT. In 1905 Prof. L. R. Jones reported that considerable oat rust was seen, but perhaps not more than an average amount.

UTAH. In 1909 stem rust was observed in Emigration canyon.

VIRGINIA. In 1909 Prof. H. S. Reed reported crown rust as locally abundant; 30 per cent of the crop injured in one county. Earliest report, May 15.

WASHINGTON. Report for 1912 by Dr. H. B. Humphrey. States that crown rust was common, causing injury to 1 to 25 per cent of the crop. Earliest report in June. Owing to our usual dry summers, the grain rusts are not serious; this year, however, owing to unusual rainfall, rusts were severe.

WEST VIRGINIA. In 1905 Prof. John L. Sheldon's report was as follows: "Oat rust was so bad in one field in Monongalia county that the plants did not head out and most of the straw was not worth cutting for fodder. Another field but a short distance away and on higher ground was not rusted and produced a heavy crop of grain. Damage from rust in general has been small and good yields are reported."

In 1906 Prof. John L. Sheldon states that loss from rust this year was greater than last (as reported in eight counties).

In 1912 stem rust reported as severe in two counties.

In 1912 crown rust said to be abundant late in the season on volunteer plants.

Crown rust reported also in 1914.

In 1915 rust generally prevalent.

WISCONSIN. In 1903 Prof. R. A. Moore reported both black stem rust and red rust.

In 1905 Professor Moore reported considerably less stem rust than in 1904; 1 per cent of crop injured. Weather conditions not favorable—dry and cool weather during early portion of growing period. Early-grown crop is freer from rust than late. In portions of the state where rust is generally prevalent farmers have been advised to grow barley and have quite generally adopted this plan.

In 1906 Professor Moore reported stem rust as somewhat less than in 1905, 2 per cent of the crop being injured. Weather conditions not favorable—dry and cool weather during early stages of development. No remedy has yet been found to keep the rust in check. Oats rust much more severely in some sections of the state than in others; most severe in the southern portion, where it sometimes reaches such an advanced stage of severity that the crop is entirely destroyed.

In 1907 Professor Moore reported oat rust as more prevalent than in 1906. Per cent of crop injured, 85. Earliest report, July 1.

In 1908 Prof. A. L. Stone reported crown rust as very prevalent; 10 per cent of crop injured. Estimated loss, $375,000. Weather conditions very favorable.

In 1908 Professor Stone reported stem rust as prevalent; 20 per cent of the crop injured. Estimated loss, $750,000. Weather conditions favorable. For the last two years abnormal spring weather has prevailed, but rust has been no worse than for five years back.

In 1909 there was less stem rust than in 1908. Weather conditions were favorable for the crop. Dry, hot weather ripened it off nicely.

In 1910 Prof. L. R. Jones and A. G. Johnson reported stem rust as much less than usual; practically none. Dry weather held rust almost perfectly in check.

In 1911 stem rust was abundant on late crops; earlier crops escaped owing to dry, warm weather.

In 1912 stem rust was general; weather conditions favorable.

In 1913 10 to 20 per cent of crop was injured.

NOTES ON OAT RUSTS IN EACH STATE.

In February, 1916, a questionnaire* was sent to each state agricultural experiment station and to men in charge of cereal field stations of the United States Department of Agriculture. The notes which follow are from the replies received, and indicate great variation in geographical distribution and seasonal occurrence of the two rusts. Much more careful study in the various states and thorough field surveys are needed to strengthen our knowledge of the two rusts of oats.

The questionnaires contained requests for information on the following points:

1. Importance of the oat crop in your state.
2. Types most commonly grown:
    - Winter—
        - Red Rustproof.
        - Winter Turf.
    - Spring—
        - Early.
        - Mid-season.
        - Late.
            - Side panicle.
            - Open panicle.
3. Usual date of sowing, heading, harvesting.
4. Occurrence of the two rusts (crown rust and stem rust).
    - Date usually first reported.
    - Frequency of occurrence:
        - Ordinary infection.
        - As an epidemic.

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* Credit is due the station men who furnished the replies, and grateful acknowledgment is here made for the assistance given.

5. Which rust seems to be the more injurious?
6. In your opinion, does either of these rusts cause sufficient injury (average and epidemic years) to constitute a "limiting factor" in oat production in any section or sections of your state? If so, give peculiar conditions existing there of soil, climate, cultural methods, etc.
7. If any work on varietal testing for rust resistance has been done, will you kindly include a statement of results to date?
8. Field or station plat observations on rust resistance of varieties, comparison of types, relation to lodging, relation to soil types or other factors of environment.
9. Any points not covered above, such as the occurrence of alternate hosts, etc.
10. Reference to any publications issued.

As in the case of the Plant Disease Survey notes, the material which follows is arranged according to states, alphabetically:

CALIFORNIA. Furnished by Mr. E. L. Adams, of the Biggs Cereal Field Station, Biggs, Cal.

1. Oats in California have not been one of the leading cereals grown, but the acreage is slowly and steadily increasing. The acreage of oats in the state has been a little more than 200,000 yearly for the past eight years. The acreages in the six leading counties in the production of oats in the state are: Stanislaus, 38,546; San Joaquin, 23,208; Merced, 19,843; San Mateo, 16,125; Madera, 10,569; and Santa Barbara, 9,494. The average yield is usually from thirty to thirty-five bushels per acre.

2. Winter varieties are best adapted to central and coastal sections. The Red Rustproof and Red Algerian varieties are usually grown in the central section, and the Red Rustproof and common California Black oat in the coastal region.

Spring oats are not as well adapted to the central and coastal sections as the winter-sown. Spring oats are grown in sections having a high elevation and late spring rains. The Sixty-day is one of the best varieties for spring seeding.

3. Usual dates of sowing, from December 1 to February 15; spring seeding, March 1 to April 1; heading, May 1 to 20; harvesting, June 1 to 25.

4. Stem rust has been noted in the Sacramento valley but it is not common. It occurs frequently in the coastal section, but the writer has never observed it. Rust is usually first reported May 1 to June 15. The infection in the Sacramento and San Joaquin valleys does little damage. Considerable damage has been reported in the coastal section during some years.

5. The writer is not familiar with the rust in the sections of the state where it frequently occurs. Stem rust is the more common in the central section of the state.

6. In the coastal section of the state warm fogs during the fruiting period of cereals are conducive to rust attacks. Rust constitutes a limiting factor in this section of the state in oat production.

COLORADO. Furnished by Otto A. Reinking, College of Agriculture, Fort Collins, Colo. The data were supplied by the Department of Farm Crops. Only general data regarding rust were kept.

1. In northern sections and high altitudes the oat crop is of considerable importance. Grown as a grain crop and as a forage crop. Frequently mixed with field peas for forage. In southern sections not of much importance. Grown mainly for feed.

2. The Red Rustproof oat is grown in the Arkansas valley from spring seeding. Spring varieties grown are: Early, Kherson; mid-season, Colorado No. 37, Colorado No. 13, Swedish Select; late, White Russian. Nearly all varieties grown are of the open-panicle type.

3. Usual dates of sowing, early April; of harvesting, July and August.

4. Only in unusually wet years do we have much rust. During season of 1915 rust was reported from a few sections, but definite information cannot be given.

6. Rust is severe in some years, but not a limiting factor; there are no data as to which rust is the more serious one.

Notes furnished by G. A. McMurdo, of the Akron cereal field station, Akron, Colo.

1. Oats are third in importance among the grain crops and second in importance among the spring-sown grains. The acreage in oats is slightly larger than that in winter wheat and

about one-third larger than that in spring wheat. It is about 60 per cent of the total wheat acreage. The acreage in corn exceeds the acreage in oats by less than 10 per cent.

2. No winter types are commonly grown. Spring types are as follows: Early, large percentage; mid-season, in favored localities; late, only in limited sections; side panicle, small percentage; open panicle, large percentage.

3. Usual dates of sowing, March and April; of heading, July 1 to September 1, depending on altitude; of harvesting, August 1 to November 1.

4. Rust is of minor importance as a crop-limiting factor with the better varieties at Akron. No crown rust so far as I know. Stem rust appears July 1 to 15; oat varieties that mature late are more subject to rust. Ordinary infections are not usually serious. This rust does not occur as an epidemic to my knowledge. Stem rust seems to be the more common and injurious one.

CONNECTICUT. Furnished by Prof. C. P. Clinton, botanist of the Agricultural experiment station, Storrs, Conn. Data on the importance of the oat crop and on varieties supplied by Prof. W. L. Slate, of the Storrs station. Professor Clinton states that no special study has been made of oat rusts in Connecticut, as they have not been as important as some of the other diseases.

1. According to the census of 1909, 60 per cent of the farms in Connecticut reported corn and 12 per cent reported oats. The number of acres of oats in the state that year was 10,207; the yield per acre was 26.8 bushels. Only 1 per cent of the improved farm land in the state was sown to oats. More oats are grown than the census shows, since it is often harvested for hay. In general importance oats rank rather high. In money value they rank fifth, hay, tobacco, corn and potatoes exceeding it.

The acreage sown will undoubtedly increase in the next decade, and the Storrs station is preparing to meet the demand for information relating to varieties (pure strains only if possible) and methods of culture. Litchfield county offers the best possibilities, and at present grows three to five times as much as the other counties.

2. No winter types are grown. Spring types grown as follows: Most growers sow "oats." Clydesdale and Banner found somewhat; these are medium early. Side-panicle types are occasionally grown, but the open-panicle types are generally found.

3. Usual dates of sowing, middle to late April, sometimes early May; of heading, late June to early July; of harvesting, late July to early August.

4. Crown rust is not uncommon. Stem rust is found at least occasionally. But few observations made and only a few collections on this host in herbarium.

5. The stem rust seems to be the most injurious, if we take into account its weakening action on stems, causing oats to lodge more easily. Thaxter, however, reported crown rust as being most destructive. The crown rust is probably the more common. There have been no complaints from injuries caused by oat rusts, but there probably would be with a greater acreage sown to this crop.

9. The æcidial stage of the stem rust on barberry has been found a number of times, especially on wild species. The æcidial stage of the crown rust *Rhamnus* has not been reported, so far as I know, from this state.

GEORGIA. Furnished by Prof. B. B. Higgins, botanist of the Georgia experiment station.

1. In 1915 there were 905,000 acres sown to oats in Georgia; in 1914, 450,000 acres. The average yield was about 20 bushels per acre; the value, 66 to 70 cents per bushel.

2. Winter types are most commonly grown. Red Rustproof is a common variety; Winter Turf is very little grown. Other varieties grown are Appler, Hastings, Bancroft, Fulghum and Virginia Turf. The first three belong to the Red Rustproof group. Spring oats are still less commonly grown. There is usually a very small acreage of Burt oats.

3. Usual dates of sowing: September 25 to October 25. Heading: Fulghum, April 22, (1915); Red Rustproof, May 3, (1915); Turf, May 10, (1915). Of harvesting: Red Rustproof, last week in May; Fulghum, May 17, (1915); Turf, June 4, (1915).

4. Rusts seem to be of very little importance on the early-maturing winter oats which are grown in this region. During the past two seasons no rust has been collected on oats, nor has it been reported by any farmer in the state.

NOTE.—Conditions may be different, however, in the coastal plain region.

IOWA. Furnished by Dr. L. H. Pammel, botanist at Iowa State College.

1. Iowa ranks ahead of all other states in oat production, and the crop is of first importance, except for corn.

2. Spring types are the only ones grown, as follows: Early, 50 per cent; mid-season, 45 per cent; late, 5 per cent; side panicle, 1 per cent; open panicle, 99 per cent.

3. Usual dates for sowing, early, March 21 to April 25, or till early May in northern Iowa; dates of heading, June 1 to first week of July; of harvesting, July 4 to first week in August.

4. (*a*) Crown rust is much more common than the stem rust; in most seasons, 5 to 10 per cent. (*b*) Stem rust, generally less than 5 per cent.

Rust is usually first reported from the middle of June to the first of July. In 1915 it was first noted on June 17. A few leaves were rusted perhaps a week earlier.

Frequency of occurrence: Ordinary infection, some rust occurs every year; as an epidemic, only occurs on late oats when climatic conditions are favorable.

The crown rust seems to be the more common and injurious one of the two species.

6. The rusts of oats constitute a limiting factor in parts of the state under peculiar conditions of culture, as follows: (1) Soil: Low ground. (2) Climate: This is the most important. (3) Cultural methods, etc.: Cultural methods do not seem to influence rust, so far as my observations go. Prof. L. C. Burnett thinks it has no influence.

Relation to lodging: If oats lodge they will rust more severely. Generally oats lodge, and then they rust badly, probably because the moisture conditions are more favorable.

Relation to soil types or other factors of environment: The richer the soil the more rust, because the tissues are more easily infected. That has been my experience over a long period of years.

9. There are few alternate hosts in the state. Where the alternate host occurs, more rust is said to occur. I have been told that in Butler county the oats leaf rust is always more severe close to the buckthorn hedges.

KANSAS. Furnished by Prof. L. E. Melchers, pathologist, Kansas State Agricultural Experiment Station.

Winter oats are not grown. Early varieties of oats most commonly grown, of the open-panicle type. Red Rustproof (Red Texas) probably most common variety; Kherson second.

Usual dates of sowing, March 15 to 20; usual date of heading, June 1; usual date of harvesting, July 1.

Crown rust of oats occurs probably annually in Kansas. Some years it is more prevalent than others. It has been rather abundant last year (1915), especially on the sheaths. In the vicinity of Manhattan reports show that it is present by June 28. Specimens sent in October 15, 1915 (young plants), showed its presence.

No epidemic of stem rust has been observed or reported in this state. A few specimens were gathered at Hays, Kan., on June 17, 1914. It was observed on a few specimens in Manhattan in June, 1915, and in October, 1915.

Oat rusts probably occur annually to a slight extent in various localities in the state, but have never been reported as an epidemic.

The crown rust is very prevalent, being more common than the stem rust, but what its damage is cannot be stated. Apparently the crop does not seem to be reduced by its presence.

Neither of the rusts of oats is of economic importance in the state.

MAINE. Furnished by Prof. W. J. Morse, of the Maine agricultural experiment station. Data on varieties and dates of seeding furnished by Dr. Frank M. Surface.

1. Of the agricultural crops of Maine oats are reported as ranking third as a wealth producer; annual yield, about 6,000,000 bushels. In the better potato-growing districts, particularly in Aroostook county, oats follow potatoes in the rotation, then one or two years in grass and clover, and then back into potatoes again.

As compared with other parts of the country, Maine, according to my observations and from all that I can learn, as a rule suffers comparatively little damage from oat rust, except with certain varieties like the Senator, which are little planted. It is possible, however, that some seasons rusts of oats may be of greater economic importance than we have thought. Compared with certain other plant diseases, it has not seemed of sufficient importance to merit any particular attention on our part. Consequently the data furnished are not as comprehensive as might be desired.

2. No winter types are grown. Spring varieties commonly grown are: Early, Kherson; mid-season, Swedish Select, Banner; late, Early Pearl. All open-panicle types, no side oats is grown.

3. Usual dates of sowing: Northern, May 15; central and southern, May 1. Heading: Northern, about July 15; central and southern, about July 1. Harvesting: Northern, September 10; central and southern, August 20.

4. Crown rust is not in our collection from Maine, but this should by no means be taken as an indication that it is not here.

Stem rust is common and widespread, but, as before stated, it does not, as a rule, do a relatively large amount of damage upon the varieties generally grown.

Date usually first reported: No data on this point.

Frequency of occurrence: Ordinary infection rather common: not epidemic.

5. Apparently black stem rust is the more common and injurious of the two. Neither of these oat rusts are serious enough to constitute a limiting factor in crop production.

The Department of Biology of this Station has been giving special attention to oat-breeding work for several years and has grown a large number of named varieties and crosses of its own making. The Senator is about the only one of these which Doctor Surface remembers especially as being attacked by rust. My own recollection is in accord with this.

MINNESOTA. Furnished by Prof. Andrew Boss, agronomist, and Drs. E. M. Freeman and E. C. Stakman, pathologists.

1. The oat crop is probably second in importance of the cereals in 1915. An acreage of 3,125,000 acres was grown, which yielded 134,375,000 bushels. Only two states, Iowa and Illinois, exceeded this production. Owing to the increase in live-stock production in the state, there is a growing demand for the coarse grain crops, and oats stands next to corn as a feed crop.

2. Types most commonly grown: Swedish Select, Archangel, White Russian, and Kherson types under many different variety names. Winter oats are not grown.

Spring varieties commonly grown are: Early, Kherson, Early Champion; mid-season, Swedish Select, Archangel; late, White Russian. Practically all of the oats grown in Minnesota are open panicle. The Improved White Russian is sold by some seedsmen as a side-panicle oat. Some of the Garten introductions also are side panicles.

4. Crown rust is practically always present, at least to some extent, and is probably the more important of the two rusts.

Some stem rust is usually present, but seldom in sufficient amount to cause damage. Date usually first reported, about June 20 to July 1. A little of both rusts practically always present. Neither usually is present in epidemic form. The crown rust more often approaches epidemic condition.

5. The crown rust seems to be the more injurious, and is also probably the more common, although the stem rust is usually also present.

The rust of oats probably does not, at least in most seasons, constitute a limiting factor of crop production.

Alternate (æcidial) hosts: *Rhamnus cathartica* (buckthorn) is commonly grown in hedges and commonly rusted.

MONTANA. Prof. D. B. Swingle, of the Montana agricultural experiment station, writes that the rusts of oats are extremely unimportant in Montana.

NEW YORK. Furnished by Prof. E. G. Montgomery, farm crops department of the New York State College of Agriculture:

1. Oats are our most important grain crop.

2. Types most commonly grown are medium maturing, branching, White Oats of Lincoln, or Swedish Select type. No winter oats are grown.

Of the spring varieties, early types are almost unknown. Practically all are mid-season, with a few late oats. Only a small part is side panicle; probably 99 per cent is open panicle.

4. Usual dates of sowing, last week of April in south New York, ten days later in north; of heading, July 10; of harvesting, August 11.

6. During the four years I have been in New York the rust has not been nearly as injurious as it usually was in Nebraska. Does not appear to be very injurious here, as a general rule.

Professor Barrus, of the plant pathology department, states that oat rust has been reported by farmers as causing serious loss in the northern counties of New York, but species is unknown.

NORTH DAKOTA. Furnished by H. L. Bolley, botanist of the North Dakota agricultural experiment station:

1. The importance of the oat crop in the state of North Dakota is second only to that of wheat; that is to say, the crop from year to year in money value and general acreage holds that position in this state.

2. Spring varieties are grown. Named in order of their prevalence, they are: Swedish Select, Sixty-day, White Russian. They say that the White Russian oat was for years the common form, but was allowed to degenerate because of poor grading. It is a very valuable oat in this region when properly handled. The Sixty-day oat is grown particularly, because it ripens early enough to escape rust attack and produces very heavy weight seed per bushel; particularly valuable because of the large size of the berry, though the grain with its husks do not indicate this. The Swedish Select, however, seems to be at the present time the hardiest and most satisfactory oat for yield and general market purposes; has rather heavy husks in proportion to berry. The weight per bushel still remains good.

3. The date of seeding will be from April 20 to May 25, or commonly along about May 10. Date of harvesting variable, according to growth season—July 25 to August 10, 12, or later, according to planting period.

4. (*a*) Crown rust is the common rust in this region; was not very destructive the past year. Should perhaps fairly be listed from 5 to 10 per cent or less for the general crop, there being cases of higher percentages due to planting out of season, etc. (*b*) Stem rust is often common in this state, but was not particularly destructive during the last year. I would say that in most cases, for the general crop, it should be listed below 5 per cent of damage.

The ordinary first appearance of stem rust on oats will be seen in the neighborhood of May 15 to 30. The epidemic form will not appear until late in July.

5. When the stem rust appears it is very much the most destructive, especially if it reaches the epidemic stage before the grain is mature. One year with another, crown rust probably causes more damage; that is, it annually cuts down a small percentage of the crop, it being the most common form and usually present in more or less injurious form, resulting in injury by the premature ripening of the leaves or foliage.

With our present knowledge, to specify definitely the soil, climatic or cultural methods or conditions which most largely influence the growth of either one of these species of rust is not possible. Apparently very much more depends upon some spring conditions which are unknown to me than to matters of culture, variety or soil. Some years the rust gets started very early, and whether it is under dry climatic conditions for the most of the season, or whether extra wet, one cannot account for the excessvie development at certain periods and not at others on any other basis than it just chanced to be that in a particular region—perhaps it is one year a dry-soil region, as south and westward from Jamestown or north and eastward from Carrington, or another year it is the heavy wet lands of the valley—there is a heavy growth of either one or other of these rusts, particularly the stem rust. My explanation is that the moisture on the leaves and the spore distribution from barberry, or perhaps the red stage from another district, just chanced to furnish a good supply of spores at the time when the infection period was ripe. In my studies I have learned to know that the general infection does not come unless the oats chanced to be in the proper stage of development—just a matter of planting a few days late or a few days early. It is a problem worthy of very careful study for a number of years in which accurate data is compiled by the same observer on the same field under daily conditions.

7. In the case of oats we have not done sufficient variety testing work to justify conclusions. We have met with conditions similar to the ones we have indicated under question 6. Variety seems to be not of much importance under certain conditions which are unknown.

9. Most people do not give much credit to the destructive work occasioned by the ordinary common barberry bushes in the development and distribution and destructive effects of stem rust. Most people do not take sufficiently into account the distributing power of the wind and the long-extended vitality of æcidiospores and of uredospores. It does not take many barberry bushes to do the work over many miles. Our experiments and studies on this question are conclusive. The barberry bush is very destructive to cereal grains in the immediate vicinity, and we lose sight of this only because the wind distributes the spores over

miles of territory. There are plenty of barberry bushes in the state of Minnesota to largely account for the damage done in North Dakota, Iowa, South Dakota and Wisconsin. These are the only conclusions based upon our experimental observations which every year show the barberry bush to be most destructive.

Notes furnished by Mr. R. W. Smith, of the Dickinson substation:

1. The oat crop is next to spring wheat in importance.

2. Types most commonly grown: Mid-season varieties of white oats, as Swedish Select, Big Four, Silvermine. A small acreage of Sixty-day type, and some late side oats. No winter oats are grown.

Spring varieties: Early, a small amount; mid-season, by far the larger part; late, a small amount. Side panicle, a small amount; open panicle, nearly all.

3. Usual dates of sowing, April 20 to May 20, averaging about first week in May; usual dates of heading, July 10 to 25, averaging about middle of July; usual date of harvesting, August 1 to 20, averaging about August 10.

4. A very slight amount of crown rust occurred in 1915. It appeared about August 10. A slight infection of stem rust in 1915. It apparently did not affect yield. Stem rust is rare in this section of the state. Ordinary infection probably about one year in three in eastern portion of state; as an epidemic very rare.

5. It is uncertain which rust is the more injurious. Did not distinguish the rust species when rust infections were observed.

6. There has been practically no serious rust epidemic at Dickinson (since the station was established in 1907) till 1915, when the wheat was badly infected, the oats only slightly. In Bottineau county (northern North Dakota) I have never observed a very serious rust epidemic (in fifteen years), but several light infections during that time. No relation between rust and lodging has been observed.

NEW JERSEY. Furnished by Prof. Mel T. Cook,* of the New Jersey agricultural experiment station.

1. Prof. Frank App, agronomist for the New Jersey agricultural experiment station, says: "The oat crop is of considerable importance in North Jersey, and is almost on a par with wheat. It, too, is used to some extent as a forage crop in the dairy regions. Its annual value is approximately $1,000,000, with an acreage of 70,000 and a production of 2,000,000 bushels."

2. Spring varieties are grown, mainly early or mid-season types.

3. Usual dates of sowing, last two weeks in March and first two weeks in April; usual dates of harvesting, latter part of July and first part of August.

4. Crown rust is the most common and injurious one, infection 25 per cent to forty per cent. Stem rust very little; less than 5 per cent. We have no complaint of rusts from farmers.

NEW MEXICO. *San Miguel county.* Furnished by M. R. Gonzales, county agriculturist, East Las Vegas.

1. Importance of the oat crop in San Miguel county: Five thousand acres in the county for 1915. There are more oats planted in the county than any other crop. It is a very poor practice, and we are discouraging the raising of such crop for the market. It is one of the main grains raised in all mountain districts.

2. Types most commonly grown: Colorado, No. 37, white oats; Swedish Select. Mixture of all kinds is two-thirds of all oats. Open-panicle types are commonly grown. Our seasons are so short that all our oats mature about the same time.

3. Usual dates of sowing, March 15 to May 15; usual dates of heading, July 1 to September 1; usual dates of harvesting, September 1 to October 1. I have not made sufficient definite observation on the subject to give desired information.

Colfax county. Furnished by V. L. Martineau, county agriculturist, Raton, N. M.

1. Importance of the oat crop in Colfax county: At the present time the oat crop is the most extensive grain crop grown in Colfax county. About 20,000 bushels were pro-

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* Professor Cook wrote as follows: "We do not look upon the cereals as of as great importance as the fruit, potato and truck crops, and therefore have given less attention to cereal diseases."

duced last year. The oat crop is likely to become less important, as yields are not large enough to make a reasonable profit.

2. Types grown: No winter oats are grown at present. Red Rustproof has been grown, but it is planted in the spring. A great many varieties of spring oats are grown here, about twenty different varieties being exhibited at our fair last year. Early varieties are grown in the mountain and mesa districts; mid-season in irrigated and plains districts; late varieties in irrigated and plains districts; side panicle, Russian side oats; open-panicle type is most common.

3. Usual dates of sowing, from the 1st of April until the latter part of May; heading takes place from the latter part of July until September 1; harvesting from August 1 until September 15.

4. Statement as to the occurrence of the two rusts: (*a*) Crown rust: 'This type of rust is present, but not as common as stem rust. (*b*) Stem rust: This type of rust is most common.

Date usually first reported: Usually appears during August.

Frequency of occurrence: Very common in all parts of the county. (*a*) Ordinary infection is nearly always present. (*b*) As an epidemic: Rust appeared as an epidemic this year (1915).

Stem rust is by far the most injurious here, and is the most common one.

Rust is a limiting factor, especially in epidemic years. Nearly all of our soils are heavy clay loam. Sandy soils are red. Climate is cool on account of the high altitude here. Rains come during July and August.

The Russian side oat seemed to be more rust resistant than any other variety I observed.

OREGON. Furnished by Prof. G. R. Hyslop, agronomist of the Oregon agricultural experiment station.

1. The oat crop is the second cereal of importance in Oregon. It yields from twelve to sixteen million bushels per year and the production is from thirty-five to forty-four bushels per acre. The bulk of the oat crop is produced in the Willamette valley section.

2. In western Oregon the open-panicled Gray Winter oat is very extensively grown. The early white spring oats of the sixty-day and Siberian type are commonly grown in eastern Oregon, while under most western Oregon conditions the mid-season or medium type, such as Swedish Select, Banner, Improved American, Three-grain and Victory, are more commonly used. The bulk of the crop of the state is of the open-panicled type. In western Oregon there is some of the side-panicled type of the Shadeland Wonder, Challenge and Eclipse varieties. Not many other side oats are grown. Practically all of the spring oats are white oats. The great bulk of the winter oats are gray oats, although in some cases there are some black oats and a few red ones.

3. The usual dates of sowing winter oats are September 15 to November 1, although they are frequently seeded up to as late as the first of December, and often gray oats are seeded in January or early February. Spring oats are seeded from mid-February until May 1, with the earlier dates of planting preferable. Oats of the winter varieties are usually harvested about the middle of July; of the spring varieties, during the first half of August.

4. I have not recognized the difference between crown rust and stem rust, but in my observations on the rust of oats I have noted that the leaf sheaths were affected very seriously as well as the blades, but have not noted such serious occurrence of rust on the stem itself. My observations have been that on all spring oats, seeded late, rust is much more injurious than on oats seeded early. Also in seasons that are rather warm and moist in June and early July the spring oats are seriously affected with rust; also the larger- and softer-stemmed varieties of oats appear to be more seriously injured than the finer- and harder-strawed types. The rust appears practically every year on some varieties.

5. Without having distinguished between the two varieties, I believe the stem rust to be the type which is most common and injurious with us.

6. I do not believe that rust may be considered serious enough to become a limiting factor in most cases. In many instances it undoubtedly reduces the yield, but still our conditions here are such that we get pretty good yields of oats. I believe this to be largely due to the rather cool and moist climate which prevails during the early growing season and the cool and somewhat dry conditions which prevail a little later.

In seasons of warm, wet weather in June and early July the spring oats always show considerably more rust than in the cooler years.

Spring oats that are seeded late in the spring, or that mature quite late, are very likely to rust much more seriously than the early to the medium varieties, with the exception noted in the answer to a previous question, that certain varieties appear to be less resistant to the rust.

7. Varietal testing of oats has been carried on for a number of years, more from the standpoint of getting yields than from the standpoint of resistance to rust. Where pronounced rusting has taken place notes have been made of it, but not according to the scale adopted by the Office of Cereal Investigations. It has simply been noted that certain sorts were very rusty or showed considerable rust. In case of varieties which did not show the presence of the disease no particular note was made.

Of the various varieties tested the ones most seriously affected with rust have been Shadeland Challenge, Shadeland Eclipse and Shadeland Wonder. I consider these three varieties to be the same, and as all of them are late, they are usually seriously affected with the disease. Improved American and Banner also usually show considerable rust. In a one-year's trial Black Victor and Black Beauty showed very serious rusting. Of the varieties which showed considerable less trouble with rust, I may mention the Sixty-day and the Kherson (which appear to be the same thing), the Three-grain and the Shadeland Climax or Swedish Select. Of the winter oats I think the most resistant type to be the Gray Winter, and the Black Winter is a type of brown oat that has also proven to be quite resistant. I believe the Black Russian to be more seriously affected than any other type of the winter oats which I have had occasion to try.

In my experience with oats there has been no difference in the rusting of the side oats or tree oats, but it has been very largely along the line of large, sappy types and the smaller-strawed types, and also along the lines of earliness and lateness. There has been no relation between lodging and the presence of rust, as conditions are such here that oats very rarely lodge.

Notes of Prof. H. S. Jackson, formerly plant pathologist:

Both the crown rust and stem rusts on oats occur in Oregon. I would not consider either one very serious, however; at least not in the Willamette valley. I have noted the stem rust quite commonly, often collecting it on volunteer oats and on *Avena fatua glabrata*. The crown rust I have found but rarely, though I suspect it is more abundant in the coast region. I have only two collections in my herbarium.

I would say regarding the crown rust, that no culture work has yet been conducted using material from the Pacific coast, so far as I am aware. I am convinced from field observations, however, that the crown rust has for its æcidial host in western Oregon, *Rhamnus purshiana*. The æcidium is very common and agrees well with the forms on other species of *Rhamnus*. The rust under discussion is noted much more commonly on several native grasses. It would be impossible to say whether or not the strain which we find occasionally on oats comes from an infection of æcidiospores from *Rhamnus purshiana*.

No æcidium has yet been collected on *Berberis* in Oregon, except the æcidium of *Puccinia kœleriæ* which occurs on *Mahonia* (*Berberis*).

PENNSYLVANIA. Furnished by Prof. C. R. Orton, pathologist, and Prof. F. D. Gardner, agronomist, of Pennsylvania State College.

1. The oat crop is surpassed only by corn and wheat in Pennsylvania.

2. No winter oats grown. Of the spring varieties, mostly mid-season varieties are grown. Early oats are becoming more popular. Mostly open-panicled oats are grown.

3. Usual dates of sowing at the Pennsylvania experiment station, April 15-20; of heading, July 4-8; and of harvesting, July 24-28; in southern Pennsylvania about two weeks earlier and in northern Pennsylvania a week to ten days later.

4. Crown rust appears yearly, but from our records, beginning 1909, it appears to have done slight damage in 1911 and 1914. It was apparently severe in 1909 and 1910, and 1913 and 1915 in some localities.

Stem rust frequently occurs in the state, but not so prevalent as crown rust. Usually first reported in July. Stem rust was prevalent in 1908 and in 1910 locally. No epidemics reported of stem rust.

5. Crown rust much more prevalent, and apparently most injurious. Early oats suffer much less than late varieties of late-planted oats.

7. No variety testing for rust resistance has been done. Varieties have been tested for yield, but no records of injury caused by rust have been made.

9. Alternate stage of crown rust has been collected in Pennsylvania, and probably occurs infrequently on *Rhamnus cathartica.*

Using the scale furnished for estimating rust, I find that our collections of the crown rust show the following per cent of infection: 1908, about 40 per cent; 1909, 25 to 40 per cent; 1913, 40 to 50 per cent; 1915, about 30 to 40 per cent.

SOUTH DAKOTA. Furnished by Mr. J. D. Morrison, of the Highmore substation.

1. Oats are an important crop in South Dakota, doing particularly well in cool, moist seasons.

2. Winter oats are not grown. The following percentages represent the distribution of types of spring varieties: Early, 70 per cent; mid-season, 28 per cent; late, 2 per cent. With regard to form of panicle: Side panicle, 1 per cent; open panicle, 99 per cent.

3. Usual dates of sowing, April 1 to May 1; of heading, June 20 to July 15; and of harvesting, July 15 to August 15.

4. Crown rust usually is not very prevalent. Stem rust is the principal rust appearing in South Dakota, and the most injurious one. It is usually first reported shortly after heading. It occurs usually only in wet seasons. Ordinary infection, 0 to 30 per cent, depending on the season and the variety of oats. Late varieties are usually more severely injured. As an epidemic, 1 to 100 per cent, usually in wet seasons, when heavy dew is followed by an extremely bright, hot day. This continuing for a week or ten days reduces the resistance to rust and produces favorable conditions for rapid spore development.

5. Soil seems to have very little influence on amount of rust. Wet seasons, when a heavy dew is followed by a hot, bright day, if continued for a week or more, produce rapid development of rust. Have noticed no influence of cultural methods on rust development.

8. Location has something to do with rapid development of rust. Wet, low ground usually shows more rapid development. No observations on comparison of types, except that early varieties are more resistant. The better word would be "evasive." Observation would indicate greatly increased lodging due to rust infection, especially in later stages of development. Climate seems to be the limiting factor in rust development.

Notes furnished by Manley Champlin, assistant agronomist of the South Dakota agricultural experiment station:

1. The oat crop usually ranks third in value, corn and wheat surpassing it.

2. No winter oats are grown. Types of common spring varieties are grown as follows: Early, Sixty-day; mid-season, Swedish Select and Silvermine; late, White Russian, in northeast section. With regard to form of panicle: Side panicle, White Russian; open panicle, Swedish Select, Sixty-day and Silvermine.

3. Usual dates of sowing, April 1 to 30; of heading, July 3 to 10; and of harvesting, August 1 to 10.

4. Crown rust rather rare, apparently does little damage. Stem rust is the most common and injurious form. Abundant, particularly in eastern section and on late varieties. Attacks both leaves and stems. Date usually first reported, June 20. Frequency of occurrence, common. Ordinary infection every season in eastern section; as an epidemic in wet seasons.

6. Rusts do constitute a limiting factor in oat growing, at least in the eastern section. Soil is medium sandy, glaciated loam varying in degree of sandiness. Precipitation, 20 to 25 inches; extremes of temperature to be expected. Summer weather frequently hot and muggy.

Often drilled on single-harrowed corn ground. Sometimes corn ground is double disked and harrowed before seeding. If oats are seeded after small grain the land is fall plowed and spring harrowed and the oats are drilled.

8. Often the weather conditions increase both rust and lodging, so that in the field it is impossible to say whether lodging is due directly to the weather or indirectly because of rust development. Rich loams with high organic content produce a rapid tender growth of straw, and therefore a crop more easily infected than the crop on poor soils.

9. There is considerable buckthorn and barberry grown for hedge and ornamental purposes, especially in the eastern part of the state. Wild barley is also plentiful, particularly in low, slightly alkaline spots. Occasional letters have been received stating that rust is more prevalent near groves than elsewhere. There are many small artificial groves in the state which were put in to secure title to the land under the old tree-claim act. These are frequently grown up to weeds and brambles, and I believe the wild barley found in such places is responsible for harboring rust spores.

TEXAS. Furnished by Supt. John F. Ross, of the Amarillo cereal field station.

1. The value of the oat crop for Texas is given as $3,700,000. It ranks ahead of wheat, but forms less than 1 per cent of the total value of the agricultural products of the state.

2. Winter Turf is one of the types of winter oats commonly grown. Spring varieties grown are late, open-panicle types.

3. Usual dates of sowing for the "panhandle" region, March; of heading, last week in May; of harvesting, first week in July.

4. Have had practically no trouble with rusts in oats in the panhandle. No detailed data are at hand. The crown rust seems to be the more common one.

VERMONT. Furnished by Prof. B. F. Lutman, pathologist of the Vermont agricultural experiment station.

1. After the corn crop, oats are the most important grain crop of Vermont. In fact, corn and oats are about our only grain crops.

Banner and Swedish are grown by many of the up-to-date farmers, and do well in this climate. The majority of the men, however, just sow "oats." The seed until recently was home-grown, but during the last ten years there has been a greater tendency to buy western oats for seed.

2. No winter oats are grown. Of the spring varieties, types of the mid-season group are principally grown.

3. Usual dates of sowing, as early as possible in April; average probably about middle of April. Usual date of heading, about middle of June. Usual date of harvesting, early in July; rarely after the middle.

Crown rust is fairly common both on the oat and on *Rhamnus* (buckthorn). Stem rust is our common rust, and the most injurious one. Date usually first reported, first to middle of June.

Frequency of occurrence: There have been very light infections in recent (five to six) years. Ordinary infection, about 10 per cent; in many cases not over 5 per cent. Neither rust seems to cause serious enough injury to be considered a limiting factor.

9. The æcidia have been almost absent from the barberry and *Rhamnus* during the past three years. I have found it difficult to get specimens, even for class use. Our early springs have been very dry, also the middle of the summer.

WASHINGTON. Furnished by E. F. Gaines, cerealist of the Washington State College.

1. The oat crop of Washington is second in importance of all farm crops, wheat being first. Until 1914 there has been a steady increase in the production of oats in Washington. There is only about one-half as much land seeded to barley as oats, and the wheat acreage is about five times that of both oats and barley.

2. Very little winter oats are grown, perhaps 1 per cent of the total. Of the spring oats it is estimated that 15 per cent are early, 75 per cent mid-season, and 10 per cent late. As to form of panicle, 15 per cent are side panicle and 85 per cent open panicle.

Usual dates of sowing, March 1 in Big Bend and River valleys, to May 1 in higher altitudes; heading, June 1 to August 10; harvesting, June 30 to September 1.

4. During my field trips last season I did not see a single case of rust on oats. A disease-survey record has been kept here for three years only, but during that time there has been no mention of the occurrence of rust upon oats. From this I am led to infer that the trouble is rather uncommon, especially in eastern Washington.

Notes by F. D. Heald, plant pathologist:

Saw no oat rust last season. Records for 1913 and 1914, the only ones available, contain no mention of oat rust. Oat rust would seem to be rather rare in this territory. This may not apply to western Washington.

6. Oat rusts may in some localities and seasons constitute a limiting factor in oat production on heavy, clayey soils and those soils very rich in humus, and where the climate is cool and moist. Cultural methods favorable to rust: Late seeding; seed bed poorly aërated.

8. Early varieties rust less than the later ones. The factors which cause rust seem to cause lodging, also, namely, overabundant humus supply, much moisture, late maturity.

WISCONSIN. Furnished by A. G. Johnson, assistant plant pathologist, and B. D. Leith, assistant agronomist, Wisconsin agricultural experiment station.

1. The oat crop is very important in Wisconsin; most extensively grown of any cereal crop. Practically every farmer grows oats.

2. No winter oats are grown. Of the spring varieties the following types are grown: Early, small amount; mid-season, by far most commonly grown; late, very small amount, only in northern part of state. With regard to form of panicle: Side panicle, very small amount in northern part of state; open panicle, by far most common.

3. Usual dates of sowing, April 1 to 25; of heading, June 10 to July 4; and of harvesting, July 15 to August 10. These dates are for the southern and central sections; in the northern part they are two to three weeks later.

4. There is great variation in the occurrence of crown rust from year to year, and in different sections; also in different fields in same section; in general, 15 to 30 per cent.

There is great variation in the occurrence of stem rust from year to year and in different sections; also in different fields in same section; in general, 10 to 50 per cent. Usually first reported latter part of June to first part of July. Ordinary infection each year. As an epidemic, no regularity; in southern and central sections more or less in 1913 and in 1915; previously none noted (as epidemic), at least for five years.

5. Stem rust seems the more injurious in cases where infections from both are parallel and equal, which happens sometimes in certain fields. Crown rust is the more common (*i. e.,* general) one.

6. Rusts are not usually a limiting factor in Wisconsin except very locally where soil is too heavily fertilized with barnyard manure, thus producing very heavy growth and consequently making conditions for infection very favorable.

7. Very meager exact data as yet on varietal resistance. Early varieties escape, *e. g.,* Kherson and Sixty-day. Late varieties always rust badly, *e. g.,* (1) side oats group, (2) *Avena sterilis* group. "Rustproof" rusts badly in Wisconsin because of late maturity. Heavy amount of rust and excessive lodging seem to be associated.

9. Buckthorn not common in Wisconsin; therefore the æcidial stage of crown rust may be regarded as practically a negligible factor. Barberry more common, and is undoubtedly one important factor in early infections. Relations of the crown rusts of wild grasses to the form on oats need to be carefully studied.

WYOMING. Prof. Aven Nelson, botanist of the University of Wyoming, writes as follows:

No doubt these rusts occur to some extent in the state, but our dry atmosphere reduces their occurrence to a minimum. Their rapid dissemination depends on warm, moist or muggy weather. Such weather occurs occasionally in the lower altitudes, but here on the Laramie plains we have neither the moisture nor the warmth to make rust epidemics possible.

Furnished by V. H. Florell, of the cereal field station at Archer, Wyo.

1. The order of importance of the small grains is: oats, wheat, barley.

2. A small acreage of winter oats is grown in the mountain valleys of western and southwestern Wyoming. Spring varieties grown are of the open-panicle type, as follows: Early, Kherson and Sixty-day; mid-season, Swedish Select, Colorado No. 37, and Welcome.

3. Usual dates of sowing, April 15 to May 1; of heading, July 1 to 20; and of harvesting, August 1 to 15.

4. Oat rusts are of very little economic importance in Wyoming. A slight infection (— 1 to 1 + per cent) of what is thought to have been stem rust was observed on every variety of oats grown at Archer in 1915, excepting Probsteier (C. I. 495). Rust first observed at Archer about August 1.

GENERAL STATEMENT.

From the data at hand it seems clear that the crown rust is much oftener reported from nearly all sections of the United States, but that in some of the northern sections of the country the distinct and often severe losses are due to the presence of stem rust in the form of an epidemic.

In some sections, particularly the winter-oat states of the southeastern United States, and in seasons favorable for its development, however, the crown rust may be the cause of appreciable losses.

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